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RESULTS OF A-7 ALOFT 'BOTTOMS UP' MODEL AND WEIGHT SENSITIVITY --ETC(U)
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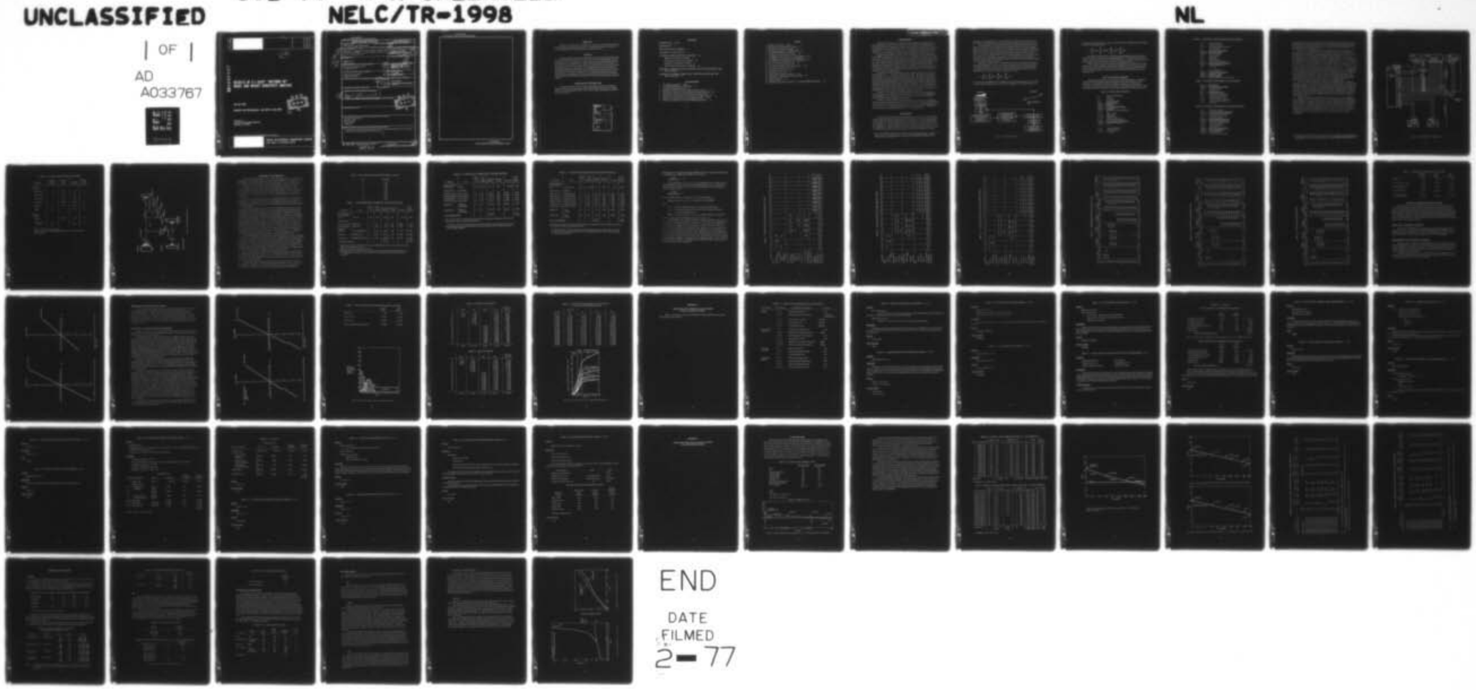

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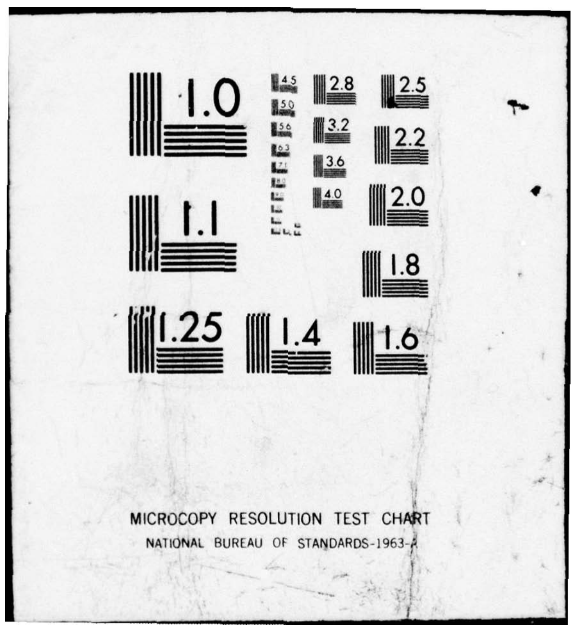
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RESULTS OF A-7 ALOFT "BOTTOMS UP" MODEL AND WEIGHT SENSITIVITY ANALYSIS

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26 July 1976

Research and Development, July 1975 to June 1976

Prepared for
NAVAL AIR SYSTEMS COMMAND
Washington, DC 20361

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NELC Technical Report 1998(TR 1998)	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER 9
4. TITLE (and Subtitle) 6 RESULTS OF A-7 ALOFT "BOTTOMS UP" MODEL AND WEIGHT SENSITIVITY ANALYSIS.		5. TYPE OF REPORT & PERIOD COVERED Research and Development rept. July 1975 to June 1976. 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) 10 R. A. RA Greenwell		8. CONTRACT OR GRANT NUMBER(s) 17
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Electronics Laboratory Center San Diego, CA 92152	16	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 63791N; W41X1 W41X1001 (NELC F228)
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Air Systems Command Washington, DC 20361	11	12. REPORT DATE 26 July 1976 13. NUMBER OF PAGES 58
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	12 59p.	15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

~~Approved for public release; distribution is unlimited.~~

14 NELC/TR-1998

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Fiber-optic communications
Wire interconnects
Fiber-optic cable
Coaxial cable

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A summary of data collected on fiber-optic and hard-wired communication-channel costs for the A-7 ALOFT is presented with the weight sensitivity to total system costs.

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OBJECTIVE

Develop cost results from the "Bottoms Up" model for A-7 ALOFT fiber-optic and wire-interconnect systems and include factors of component procurement quantities, life cycle cost justifications, and weight sensitivity to total system costs.

RESULTS

The investigations and analyses clearly indicated definite economic benefits would be gained with a fiber-optic interconnect system for the A-7 aircraft when EMI and EMP criteria were taken into consideration. Current research and development dollars drive the total differential costs ("Bottoms Up" model) of fiber-optics above the total coaxial differential costs, but the investment and operation and support costs are less for fiber-optics than the alternative wire configurations. The cumulative cost-to-benefit evaluation, excluding EMI and EMP criteria, indicate that the fiber-optics system is superior to the TSP subsystem and, at a 90-percent confidence level, the fiber-optic subsystem is more beneficial than the coaxial subsystem. Taking into consideration aircraft-carrier EMI requirements and future aircraft EMP criteria, fiber-optics technology clearly provides substantial benefits.

ADMINISTRATIVE INFORMATION

Work was performed by the Systems Analysis Group, Office of the Technical Director, for the Naval Air Systems Command under Program Element 63791N, Project W41X1, Task Area W41X1001 (NELC F228). This document was approved for publication on 26 July 1976.

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CONTENTS

ILLUSTRATIONS

TABLES

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INTRODUCTION

Initial cost results have been completed for the A-7 ALOFT fiber-optic subsystem and two alternative wire-interconnect subsystems (coaxial and twisted shielded-pair). Scenarios have also been developed for the weight sensitivity analysis to determine the effectiveness assessment for the economic-analysis effort. The purpose of this report is to provide the "Bottoms Up" cost results, which include the basic assumptions, component-procurement quantities, and cost justifications, as well as the weight sensitivity to total systems costs.

Included in this report is a summary of the data collected by the Naval Postgraduate School (NPS) to formulate their "A" factors (ref 1). The NPS thesis developed a cost model to determine the differential or relative cost difference between aircraft signal wiring consisting of either coaxial cable or twisted shielded-pair (TSP) cable, and wiring consisting of fiber-optic cable. NPS completed an industry survey, specifically using the Delphi Technique, to collect data on differential cost factors for the A-7 Cost Model. The Naval Electronics Laboratory Center (NELC) performed a second iteration of this survey to refine the range of the initial results. The sources, remarks, and ranges from this survey by the respective cost elements are presented in Appendix A.

The experience gained by McDonnell Aircraft Company (McAIR) in the fabrication and installation of fiber optics is also discussed in this report. McAIR used their engineers and technicians to perform industrial processing work in the same manner as they would for future aircraft. The results of these time-and-motion studies are presented in Appendix B. The A-7 Navigation/Weapon Delivery Subsystem (NWDS) was utilized as the basis for future aircraft fabrication and installation. Each of the three candidate systems (coaxial, twisted shielded-pair, and fiber-optic) was studied to collect pertinent time and motion information. The steps in the installation study included unbag, lay-out, route, clamp, string-tie, hookup bulkhead adapter and connectors, feed-through, inspect, and check-out. The fabrication study included cut and identify, connect terminations, inspect, and checkout.

Hardware cost summaries are also provided in this report to establish production schedules, quantity buys, and types of material procured for coaxial and twisted shielded-pair configurations. The differential costs are presented by year and are discounted to present worth for the three alternative configurations.

Finally, the results reflect the impact upon the life-cycle cost of the A-7 aircraft caused by changes in total aircraft weight and Mean-Flight-Hours-Between-Failures (MFHBF). The variables were driven initially by potential weight changes in the data-transmission system. The cost benefits were computed parametrically and are integrated with the "Bottoms Up" results in tabular and graphical representations in the following sections.

BACKGROUND

The A-7 ALOFT economic analysis was undertaken in July 1975 at NELC with the support of NPS and McAIR. The purpose of this economic analysis was to develop credible cost projections for three performance-equivalent cable systems: coaxial, twisted shielded-pair, and fiber-optic. These cost projections were generated by an approach which utilized two techniques: one which computed very specific costs for the fiber-optic and wire systems (the "Bottoms Up" technique); and the other which computed the total weapon-system costs resulting from the inclusion of the field-operation systems (the "Top Down" technique).

1. Johnson, RL, CDR USN, and EW Knoblock, LCDR USN, The A-7 ALOFT Cost Model: A Study of High Technology Cost Estimating, Thesis, Naval Postgraduate School, Monterey, California, 1976

This approach is depicted in figure 1. Each element is a component of the Life-Cycle Cost (LCC) model. The "Bottoms Up" model results become inputs to the "Top Down" model.

The "Bottoms Up" cost model discussed in this report is designed to reflect the cost differences between systems. Differential cost modeling, the first step in the cost analysis, applies to the "deltas" in costs of the systems. The second step is an expanded "Top Down" analysis to measure the effects of options on aircraft LCC. This "Top Down" model involves changes in aircraft size which result from possible weight savings that occur when fiber optics are used or the possible weight increases caused by increased wire and air-frame shielding required to meet performance requirements. The "Top Down" model includes cost categories normally used with the Advanced Design Level (ADL) studies at McAIR for making projected weapon-system cost estimates.

Basically, the "Bottoms Up" or differential cost model is a summation of changes in costs discounted over time. These cost categories contain five research, development, test, and evaluation (RDT&E) cost elements, six nonrecurring-investment cost elements, three recurring-investment cost elements, and four Operating and Support (O&S) cost elements. Summing these cost elements results in an equation of the form:

$$C = \sum_{i=1}^{5} R_i + \sum_{i=6}^{11} NRI_i + \sum_{i=12}^{14} RI_i + \sum_{i=15}^{18} + 0_i ,$$

where the R_i are the RDT&E costs, the NRI_i are the nonrecurring investment costs, the RI_i are the recurring investment costs, and the 0_i are the O&S costs. For the fiber-optic costs,

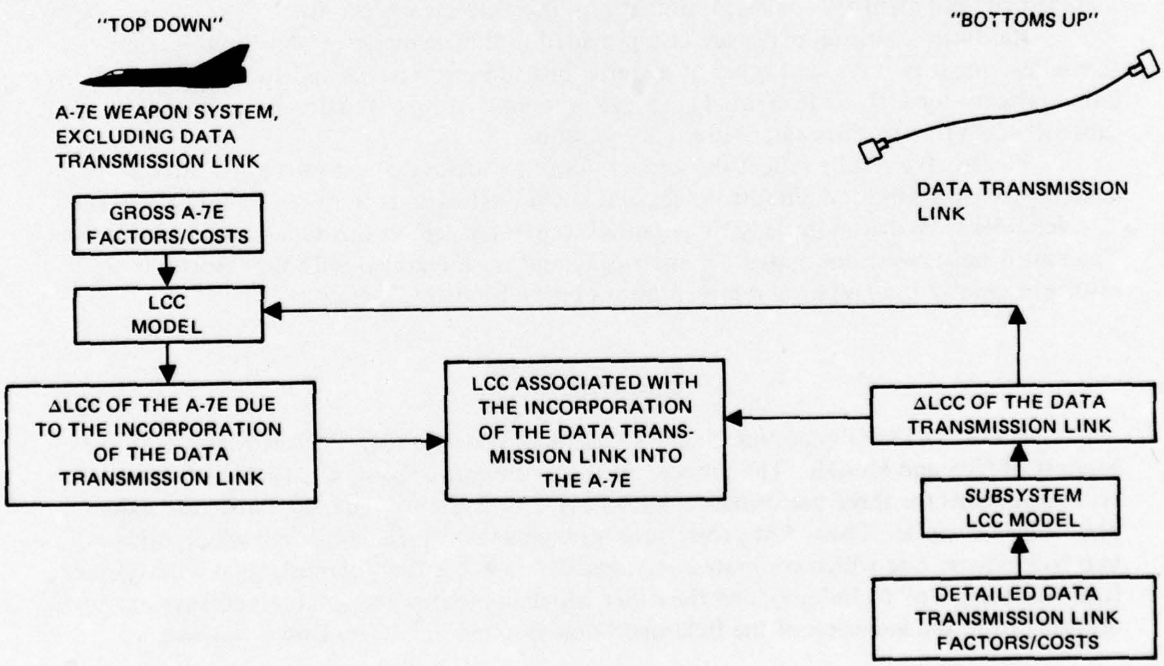

Figure 1. Two-level LCC approach.

the equation is rewritten with A's, which are coefficients from a Delphi Study. The resulting equation is of the following form:

$$C = \sum_{i=1}^{5} A_iR_i + \sum_{i=6}^{11} A_iNRI_i + \sum_{i=12}^{14} A_iRI_i + \sum_{i=15}^{18} A_i0_i$$

The Delphi technique was developed by the Rand Corporation and is considered an acceptable means for developing data for emerging systems. Coefficients have been developed for each differential cost element by NPS. When costs are zero for coaxial, as in the case of test equipment, fiber-optic dollar estimates have been made by NPS.

Tables 1 through 4 present the selected cost categories for the "Bottoms Up" model with the cost elements underlined. Not all of the elements will have costs for coaxial cable; however, there will be a cost for each fiber-optic cost element as supplied by NPS. Initial results of these differential cost elements have been determined and are presented in the following section.

COST ANALYSIS DEVELOPMENT

When this study began, it was assumed that a TSP wire-interconnect configuration could not meet the multiplexed data-rate requirements and would, therefore, not be evaluated. The economic analysis was developed to compare only a coaxial wire-interconnect configuration to a fiber-optic subsystem. The primary reason for this was that the engineering design would be the same for both alternatives and each alternative would

TABLE 1. RDT&E COST CATEGORY.

1.0	Research and Development
1.1.1	Contractor
1.1.2	Government
1.2.1.1	Program Management
1.2.1.2	Design Engineering
1.2.1.3	Fabrication
1.2.1.4	Contractor Development Tests
1.2.1.5	Test Support
1.2.1.6	Producibility Engineering & Planning
1.2.1.7	Data
1.2.1.7.1	Engineering Data
1.2.1.7.2	Support Data
1.2.1.7.3	Management Data
1.2.1.7.4	Technical Orders & Manuals
1.2.1.8	Peculiar Support & Test Equipment
1.2.1.10	General and Administrative
1.2.1.11	Fee
1.2.2.1	Program Management
1.2.2.2	Test Site Activation
1.2.3.3	Government

TABLE 2. INVESTMENT (NONRECURRING) COST CATEGORY.

2.1.1	Program Management
2.1.3.1	Production Engineering
2.1.3.4	Manufacturing Support Equipment
2.1.4	Technical Support
2.1.5	Initial Spares and Repair Parts
2.1.6.3.2	Maintenance Training
2.1.6.3.3	Instructor Training
2.1.7.1	Engineering Data
2.1.7.2	Support Data
2.1.7.3	Management Data
2.1.7.4	Technical Orders & Manuals
2.1.10	Peculiar Support & Test Equipment
2.1.12	General & Administrative
2.1.13	Fee or Profit
2.2.1	Program Management
2.2.2.2	Training Devices & Equipment
2.2.2.3.2	Maintenance Training
2.2.2.3.3	Instructor Training
2.2.3	Production Acceptance Test & Evaluation

TABLE 3. INVESTMENT (RECURRING) COST CATEGORY.

3.1.1	Manufacturing
3.1.2.1	Purchased Equipment and Parts
3.1.2.2	Subcontracted Items
3.1.2.3	Other Material
3.1.3	Sustaining Engineering
3.1.4	Quality Control and Inspection
3.1.5	Packaging and Transportation
3.1.6.2	Site/Ship/Vehicle Conversion
3.1.6.3	Assembly Installation and Checkout
3.1.8	General and Administrative Costs
3.1.9	Fee or Profit

TABLE 4. OPERATING AND SUPPORT COST (O&S) CATEGORY.

4.1.6	Other Operations Costs
4.2.1.1.1	Organizational Maintenance Personnel
4.1.1.1.2	Intermediate Maintenance Personnel
4.1.1.1.3	Depot Maintenance Personnel
4.2.1.2	Maintenance Facilities
4.2.1.3	Support Equipment Maintenance
4.2.2.1.1	Organizational Supply Personnel
4.2.2.1.2	Intermediate Supply Personnel
4.2.2.1.3	Depot Supply Personnel
4.2.2.2	Supply Facilities
4.2.2.3	Spare Parts and Repair Material
4.2.2.4.1	Inventory Management
4.2.2.4.2	Inventory Holding
4.2.2.5	Transportation and Packaging

meet the multiplexed data-rate requirements. However, after several meetings, it was determined that most aircraft companies prefer TSP to coaxial and would rather make extensive design changes to use TSP rather than coaxial. Hence, this study now compares three configurations, TSP, coaxial, and fiber-optic.

Several basic parameters had to be established prior to the input of data into the "Bottoms Up" model. Production schedules and quantities had to be established for each alternative design configuration. Escalation and strategic commodity rate increases as well as experience-curve estimates had to be established for each alternative. The base year for the economic analysis was established as beginning 1 January 1977. A period of three years was allocated for research, development, test, and evaluation (RDT&E) of a subsystem design. An acquisition cycle of four years and an anticipated operational life of ten years, without a Service Life Extension Program (SLEP), were established. The basic A-7 NWDS is the baseline design in a total production schedule of 812 A-7E aircraft. Of these 812 aircraft, twelve are test vehicles the costs of which are included in RDT&E fabrication costs. The remaining 800 aircraft will be delivered at the rate of 80 in 1980 and 240 each year in 1981 through 1983. It is also assumed that, of the 800 aircraft, 675 will be operational vehicles. The utilization rate is assumed to be 35 hours per month for nine of the ten years of operation. The remaining year is considered to be a wartime operational environment and the operational time is assumed to be 12 hours per day since the A-7 is a daylight fighter aircraft. A-7E attrition rates in Southeast Asia are also assumed for survivability analysis.

The coaxial, TSP, and fiber-optic systems have components which are similar to equipment presently in use and which have similar designs and functions. Due to the limited bandwidth capability of TSP, one of the fiber-optic (or coaxial) point-to-point connections in the ALOFT subsystem requires two additional TSP lines. Thus, the number of TSP wires is increased to fifteen as compared to thirteen in the ALOFT configuration. It is assumed that the only changes to the ALOFT adapter boxes will be the addition of two line drivers and receivers to accommodate the additional TSP lines and that no internal adapter box design will be required.

Figure 2, adapted from an earlier NELC document (ref 2), is an overall diagram of the A-7 ALOFT connections using TSP. Note the two additional lines required between the modified NWDS computer and the cockpit-area adapter. Consistent with good design practice, two harnesses are required: one from the modified NWDS to the left-hand bay, right-hand bay, ASCU and FLR E/O adapters and to the bulkhead feedthrough; one from the bulkhead feedthrough to the cockpit area E/O adapter. Table 5 is a list of the TSP wire lengths and the associated connectors for the two harnesses. Figure 3 is a general layout of the harnesses as they would be manufactured to accommodate the TSP subsystem configuration.

2. Naval Electronics Laboratory Center Technical Document 435, A-7 ALOFT Economic Analysis Development Concept, by RA Greenwell, LA Sadler, SW Green, JR Ellis, GM Holma, and TA Meador, 1975

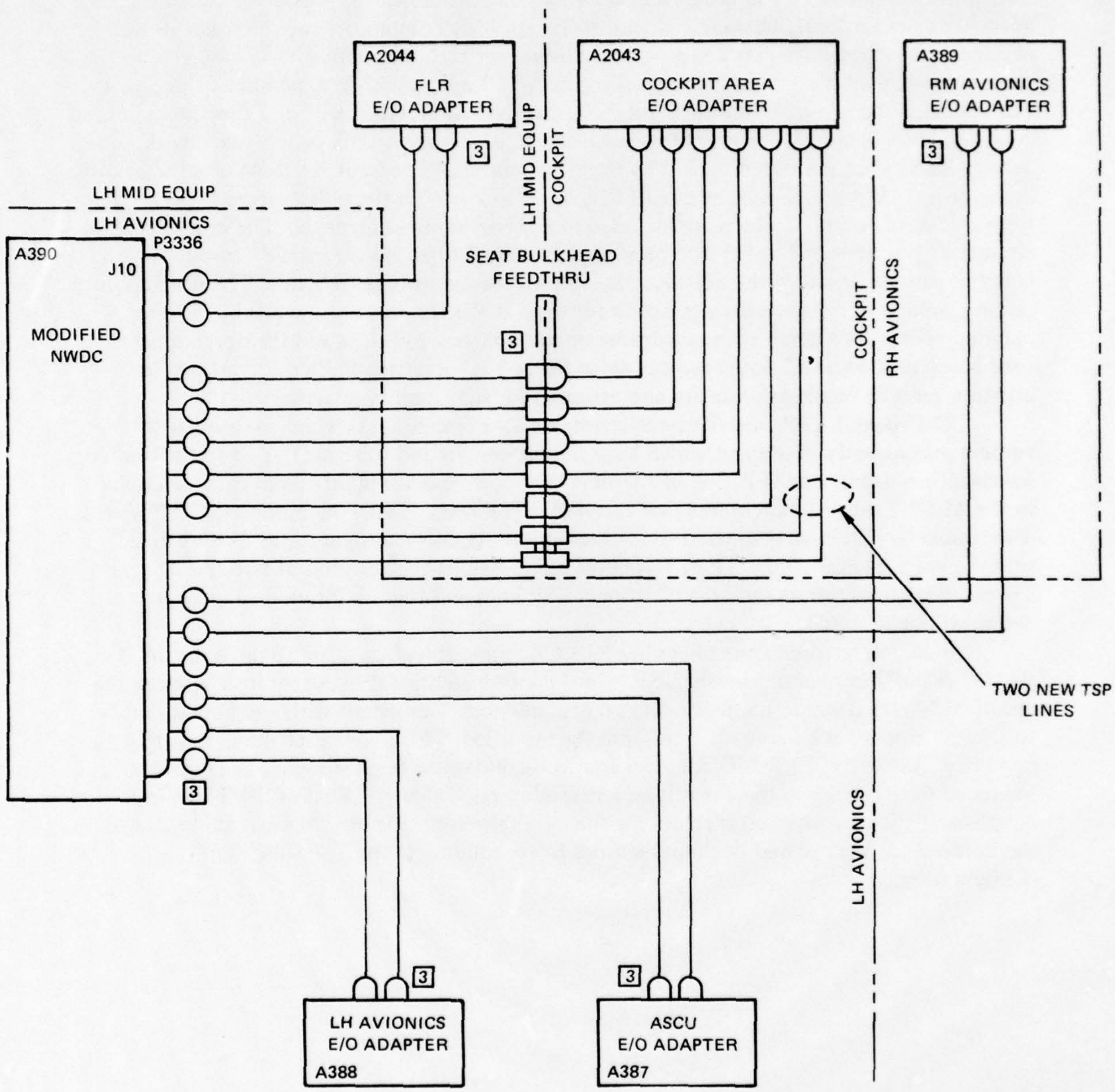

Figure 2. A-7 ALOFT TSP interface configuration.

TABLE 5. A-7 ALOFT TSP WIRES AND CONNECTORS.

Termination Name	Number of TSP Wires at Connector*	Length of Each Wire (cm)	Connector Number **	Number of Pins on Connector
Harness A				
RHA Adapter	2	231.1	8-35	6
LHA Adapter	2	236.2	8-35	6
ASCU Adapter	2	175.3	8-35	6
FLR Adapter	2	403.9	8-35	6
Bulkhead	7	157.5	12-35	22
NWDC	(15)	–	14-35	31
Harness B				
Bulkhead	7	530.9	12-35	22
Cockpit-Area Adapter	(7)	–	12-35	22

*ST5M1212-002 TSP or "twin coax" used

**X-35 is an abbreviation for MS27499 TXF35S (see figure 3). The connectors meet MIL-STD 38999.

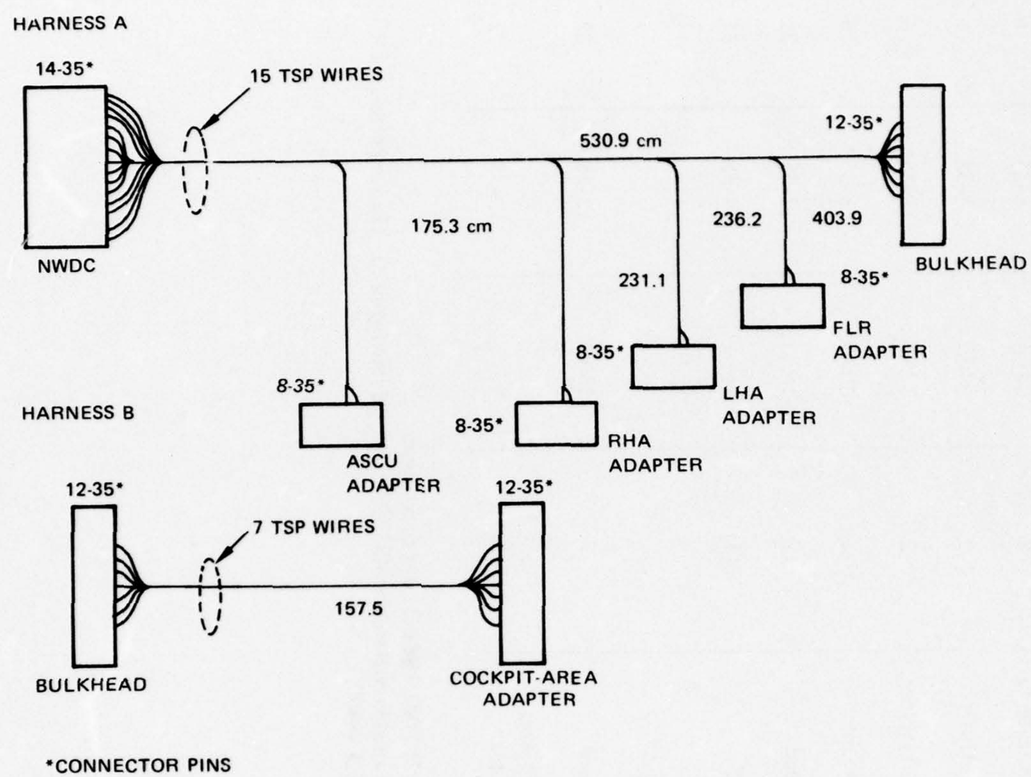

Figure 3. A-7 ALOFT TSP harness layout.

"BOTTOMS UP" COST RESULTS

Some books have been written on the subject of cost estimating in new technologies and all warn of the potential problems and hazards faced by someone venturing into a new field looking for nonexistent data. Cost data in the field of fiber optics represent no exception. Such data exist only in limited forms and many times are considered as proprietary.

The field of fiber optics today is infantile and its future is speculative at best. There is no high demand for quality fiber-optic cable nor associated fiber-optic components. Fiber-optic cable and component manufacturers have been unable to establish a production base upon which to project (predict) future prices. Users and potential users of fiber-optic technology have only a minimal data base on which to build and expand their fiber-optic applications.

Extensive research and development are required to establish both a high demand for quality fiber-optic cable/components and the production base necessary to reduce the cost of such items. As additional uses for fiber-optic technology are discovered and fiber-optic cable/component manufacturers strive to reduce manufacturing costs, available cost data will become more accurate.

As presented in Appendix A, initial cost data were gathered with the use of Delphi questionnaires for fiber-optic, life-cycle cost elements. Appropriate Delphi questionnaires were distributed to both aircraft and fiber-optic manufacturers. Telephone and personal interviews were then conducted with manufacturers and other organizations, as appropriate, to finalize the data collection. From the data-collection effort, cost factors were calculated for the fiber-optic cost elements. These cost factors are summarized in table A-1 of Appendix A. Except where noted, the cost factor is the ratio of the fiber-optic cost to the cost of "equal-functions" performance using coaxial cable. The coaxial subsystem costs are based upon the component types and quantities specified in reference 2. The cost factor can be explained by observing the cost element number 1.2.1.2, Design Engineering, as an example. The cost factor value of 0.80 signifies that the estimated aircraft design-engineering cost for electrical subsystems using fiber-optic technology would be only 80 percent of the design-engineering cost using coaxial cable technology. For some cost elements, where coaxial costs are not applicable, the fiber-optic costs are estimated actual dollar values.

After establishing the related differential costs of coaxial and fiber optics, production quantities had to be established for the three alternative configurations and then the actual buy amounts were established. A basic assumption on escalation and strategic commodity-rate increases was established for the purpose of purchasing copper-wire components. Appendix B explains current cost increases of several strategic materials as well as fabrication and installation times for the three alternative configurations. Most vendors and industries assume a 10-percent inflation rate and an annual rate of increase of one percent for strategic-resource utilization. Table 6 presents the inflation factor for a ten-year period.

These values in table 6 are used to estimate material buys over average time periods. For example, investment costs are based upon 1980 dollars and support-materials costs are based upon 1985 dollars from the base year, 1976. Tables 7, 8 and 9 present the production costs for each subsystem configuration. Component descriptions, types, quantities required, and unit costs are also provided.

The remaining costs are based upon estimated values from existing A-7 cost data. The time-and-motion studies in Appendix B provided estimated labor hours for fabrication and installation. Additional costs are estimated ratios from A-7 costs. Initial-spares costs are a function of the ratio of A-7 miscellaneous subsystem initial spares (INSPAR) to

TABLE 6. INFLATION PLUS STRATEGIC RESOURCE FACTOR.

Year	11% Factor
1	1.000
2	1.110
3	1.232
4	1.368
5	1.518
6	1.685
7	1.870
8	2.076
9	2.305
10	2.559

TABLE 7. A-7 NWDS FIBER-OPTIC SUBSYSTEM, AFTER MULTIPLEXING.

Component	Type	Req/ Qty/ AC	Unit Cost* (dollars)	Cost/AC (dollars)	Production Total AC	Total Qty	Total Cost** (dollars)
Single Cable/Wiring Fiber Optic Cable Valtec	L20-262-2	56 m	0.50 m	28.00	800	44.8 km	22 400
Signal Connectors							
Terminal Connector	IBM/L20-242	13	0.75	9.75	800	10 400	7800
Pressure Bulkhead	NELC/6507	5	1.00	5.00	800	4000	4000
Multichannel Bulkhead	ITT Cannon/DBK-4B	1	25.00	25.00	800	800	20 000
Signal Driver	IBM/SPX2231***	13	15.00	195.00	800	10 400	156 000
Signal Receiver	IBM/HB5082-4207***	13	5.00	65.00	800	10 400	52 000
TOTAL COSTS/SYSTEM:				327.75			262 200

*Unit costs are projected to 1980 and are based on large established production rates with quantities procured of 10 000 or more and/or 50 km or more.

**Total costs are rounded to nearest hundred dollars.

***Signal Driver & Receiver numbers are based on the Spectronics LED and Hewlett-Packard PD purchased for the A-7 ALOFT Project. However, the costs are estimated by Air Force projections of monolithic component development.

TABLE 8. A-7 NWDS COAXIAL SUBSYSTEM, AFTER MULTIPLEXING.

Component	Type	Req/ Qty/ AC	Unit Cost* (dollars)	Cost/AC (dollars)	Production Total AC	Total Qty	Total Cost** (dollars)
Single Cable/Wiring							
Coaxial Cable	RG-316	56 m	0.418 m	23.41	800	44.8 km	18 700
Signal Connectors	SELECTRO						
Terminal Connector	50-622-9188-31	36	1.68	60.48	800	28 800	48 400
Bulkhead Receptacles	50-647-4576-31	26	1.68	43.68	800	20 800	35 000
Pressure Bulkhead	50-675-7000-31	5	3.43	17.15	800	4000	13 700
Printed Circuit Card	50-651-0000	26	1.96	50.96	800	20 800	40 800
Signal Drivers	SN54S140 TEXAS INST.	13	1.85	24.05	800	10 400	19 200
Signal Receivers	SN54S132 TEXAS INST.	13	5.33	69.29	800	10 400	55 400
TOTAL COSTS/SYSTEM:				289.02			231 200

*Unit costs are in current 1976 dollars and are based on production quantities of 10 000 and/or 50 km or more.
**Total costs are rounded to the nearest hundred dollars.

For 1980 cost estimates a 10-percent escalation rate has been determined by most vendors as well as a 1-percent cost increase due to strategic commodity usage in the coaxial wired system. Thus, the 1980 cost estimate is: 1.368 × 231 200 = $316 300.

TABLE 9. A-7 NWDS TWISTED SHIELDED-PAIR, AFTER MULTIPLEXING.

Component	Type	Req/ Qty/ AC	Unit Cost* (dollars)	Cost/AC (dollars)	Production Total AC	Total Qty	Total Cost** (dollars)
Single Cable/Wiring Twisted Shielded Pair	ST5M1212-002	70 m	0.705 m	49.35	800	56 km	39 500
Signal Connectors	BENDIX						
6 Pin Connectors	MS27499T8F35P	4	12.26	49.04	800	3200	39 200
6 Plug Connectors	MS27473T8F35S	4	11.61	46.44	800	3200	37 200
22 Pin Connectors	MS27474T12F35P	3	17.28	51.84	800	2400	41 500
22 Plug Connectors	MS27473T12F35S	3	14.73	44.19	800	2400	35 400
31 Pin Connectors	MS27499T14F35P	1	14.80	14.80	800	800	11 800
31 Plug Connectors	MS27473T14F35S	1	17.46	17.46	800	800	14 000
Signal Drivers	55109 Fairchild	15	3.55	53.25	800	12 000	42 600
Signal Receivers	55107 Fairchild	15	3.38	50.70	800	12 000	40 600
TOTAL COSTS/SYSTEM:				377.07			301 800

*Unit costs are in current 1976 dollars and are based on production quantities of 100 or more and/or 50 km or more.
**Total costs are rounded to the nearest hundred dollars.

For 1980 cost estimates a 10-percent escalation rate has been determined by most vendors as well as a 1-percent cost increase due to strategic commodity usage in the twisted shielded-pair system: Thus, the 1980 cost estimate is: 1.368 × 301 800 = $412 900.

40 percent of A-7 subsystems procurements (PROC) which can be expressed mathematically as: INSPAR factor = INSPAR/(0.40)(PROC). The factor is:

$$\frac{196.247}{(0.40)(463.828)} \cong 1.06$$

For replenishment spares, the cost factor is estimated in the same manner where the replenishment spares factor is equal to the replenishment spares cost for miscellaneous subsystems and airframe divided by 40 percent of the subsystem and airframe procurement costs. The factor is equal to:

$$\frac{75.004}{(0.40)\ 1591.618} \cong 0.12$$

Thus, replenishment spares are estimated for a 10-year operational life as:

REP Spares/Year = (0.12)(1.518)/10 (TPROC) = 0.0182 (TPROC)

where

0.12	=	the A-7 replenishment spare ratio for electrical subsystems,
1.518	=	the average escalation rate for copper wire configured subsystems,
10	=	10 year operational life, and,
TPROC	=	total procurement costs for the A-7 NWDS interconnect configuration.

Tables 10, 11 and 12 list the differential costs by element and year.

DOD Instruction 7041.3 requires that future dollars be discounted to present worth. Where possible, inflated costs must also be determined. For the three alternatives presented in this study, a labor cost-inflation rate of 5 percent is assumed and the required discount rate of 10 percent is applied to all costs to determine total life-cycle costs. Tables 13, 14, and 15 list the total dollars by year and generic cost categories. From these discount totals, it can be seen that the coaxial alternative is the least costly in terms of total discounted dollars and twisted shielded-pair is the most costly. R&D dollars drive the total discounted cost of fiber optics above the total coaxial costs, but the investment operation, and support costs are less for fiber optics than for coaxial or TSP. All the costs in the tables are rounded to the nearest hundred dollars. Table 16 provides a breakdown of total costs not discounted for the major LCC categories. Only RDT&E costs are greatest for fiber optics as compared to the two alternative wire configurations.

TABLE 10. FIBER-OPTICS DOLLAR DIFFERENTIAL COSTS.

Calendar Year	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
RDT&E																	
0.8 Engineering	1600	1600	900														
0.95 Fabrication Labor		2100	4300														
1.05 Material		6800															
— Contractor Development Test	100 000																
— Test Support			100 000														
— Peculiar Support & Test Equipment		100 000															
Investment Nonrecurring																	
1.33 Initial Spares				26 800	83 500	83 500	83 500										
1.30 Peculiar Support				15 600	46 700	46 800	46 700										
2.00 Training Devices				3000													
Maintenance Train. (Contract)				4000													
Maintenance Train. (Contract)						4000	4000										
Instructor Training					4000	4000											
Investment Recurring																	
0.80 Manufacturing Labor				16 200	48 700	48 700	48 700										
Material			1800	4800	4600	4800											
0.83 Purchased Parts			25 300	78 800	78 800	78 800											
0.80 Sustaining Engineering				2200	6500	6500											
Operations & Maintenance																	
Organizational								100	100	100	100	100	100	100	100	100	100
Support Equipment								9600	9600	9600	9600	9600	9600	9600	9600	9600	9600
Spare Parts							1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	
Inventory Management								4100	1300	1300	1300	1300	1300	1300	1300	1300	1300
TOTAL BY YEAR	101 600	110 500	132 300	150 400	272 100	277 100	191 400	15 700	12 900	12 900	12 900	12 900	12 900	12 900	12 900	12 900	11 000
NO. OF AIRCRAFT		4	8	80	240	240	240	675	675	675	675	675	675	675	675	675	675

TABLE 11. COAXIAL DOLLAR COST-BREAKDOWN TABLE.

Calendar Year	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
RDT&E																	
Engineering	2000	2000	1100														
Fabrication Labor		2200	4500														
Material		6500															
Investment Nonrecurring																	
Initial Spares				33 500	100 600	100 600	100 600										
Peculiar Support				12 000	35 900	36 000	35 900										
Training Devices				1500													
Investment Recurring																	
Manufacturing Labor				20 300	60 900	60 900	60 900										
Material			2300	6000	5800	6000											
Purchased Parts			31 600	94 900	94 900	94 900											
Sustaining Eng				2800	8100	8100	8100										
O&M																	
Organizational								200	200	200	200	200	200	200	200	200	200
Support Equipment								12 000	12 000	12 000	12 000	12 000	12 000	12 000	12 000	12 000	12 000
Spare Parts							5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	
Inventory Management								2600	800	800	800	800	800	800	800	800	800
TOTAL BY YEAR	2000	10 700	39 500	171 000	306 200	206 700	209 200	20 500	18 700	18 700	18 700	18 700	18 700	18 700	18 700	18 700	13 000
NO. OF AIRCRAFT		4	8	80	240	240	240	675	675	675	675	675	675	675	675	675	675

TABLE 12. A-7 ALOFT TSP DOLLAR COST-BREAKDOWN TABLE.

Calendar Year	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
RDT&E																	
Engineering	2000	2000	1100														
Fabrication Labor		2500	4900														
Material		7200															
Investment Nonrecurring																	
Initial Spares				43 800	131 300	131 300	131 300										
Peculiar Support				15 700	47 200	47 300	47 200										
Training Devices				1900													
Investment Recurring																	
Manufacturing Labor				25 300	76 000	76 100	76 000										
Material			8100	22 500	22 600	22 500											
Purchased Parts			41 300	123 900	123 900	123 800											
Sustaining Eng				3400	10 100	10 200	10 100										
O&M																	
Organizational								200	200	200	200	200	200	200	200	200	200
Support Equipment								15 700	15 700	15 700	15 700	15 700	15 700	15 700	15 700	15 700	15 700
Spare Parts							7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	
Inventory Management								2600	800	800	800	800	800	800	800	800	800
TOTAL BY YEAR	2000	11 700	55 400	236 500	411 100	411 200	272 100	26 000	25 200	25 200	25 200	25 200	25 200	25 200	25 200	25 200	16 700
NO. OF AIRCRAFT		4	8	80	240	240	240	675	675	675	675	675	675	675	675	675	675

TABLE 13. FIBER-OPTICS DOLLAR COSTS BY YEAR.

Calendar Year	RDT&E		Nonrecurring Investment		Recurring Investment		Operation and Support		Total Annual Costs		Labor Costs Inflated		Total Costs	Discounted Costs 1976
	Labor	Material	Labor	Material	Labor	Material	Labor	Material	Labor	Material	5%			
1976														
1977	101 600								101 600		1.050	106 700	106 700	101 800
1978	103 700	6800							103 700	6800	1.103	114 400	121 200	105 100
1979	105 200					27 100			105 200	27 100	1.158	121 800	148 900	117 300
1980			4000	45 400	18 400	83 600			22 400	129 000	1.216	27 200	156 200	112 000
1981			4000	130 200	55 200	83 300			59 200	213 500	1.276	75 500	289 000	188 400
1982			8000	130 300	55 200	83 600			63 200	213 900	1.340	84 700	298 600	176 800
1983			4000	130 200	55 200			1900	59 200	132 100	1.407	83 300	215 300	115 800
1984							13 800	1900	13 800	1900	1.478	20 400	22 300	10 900
1985							11 000	1900	11 000	1900	1.441	17 100	19 000	8500
1986							11 000	1900	11 000	1900	1.629	17 900	19 800	8000
1987							11 000	1900	11 000	1900	1.711	18 800	20 700	7600
1988							11 000	1900	11 000	1900	1.796	19 800	21 700	7200
1989							11 000	1900	11 000	1900	1.886	20 700	22 600	6900
1990							11 000	1900	11 000	1900	1.980	21 800	23 700	6500
1991							11 000	1900	11 000	1900	2.079	22 900	24 800	6200
1992							11 000	1900	11 000	1900	2.183	24 000	25 900	5900
1993							11 000		11 000		2.292	25 200	25 200	5200
TOTAL	310 500	6800	20 000	436 100	184 000	277 600	112 800	19 000	627 300	739 500	–	822 200	1 561 600	990 100

TABLE 14. COAXIAL DOLLAR COSTS BY YEAR.

Calendar Year	RDT&E Labor	RDT&E Material	Non-recurring Investment Material	Recurring Investment Labor	Recurring Investment Material	Operation and Support Labor	Operation and Support Material	Total Annual Cost Labor	Total Annual Cost Material	Labor Costs Inflated 5%	Labor Costs Inflated	Total Costs	Discounted Costs 1976
1976	—												
1977	2000							2000		1.050	2100	2100	2000
1978	4200	6500						4200	6500	1.103	4600	11 100	9600
1979	5600				33 900			5600	33 900	1.158	6500	40 400	31 800
1980			47 000	23 100	100 900			23 100	147 900	1.216	28 100	176 000	126 200
1981			136 500	69 000	100 700			69 000	237 200	1.276	88 000	325 200	212 000
1982			136 600	69 000	100 900			69 000	237 500	1.340	92 500	330 000	195 400
1983			136 500	69 000			5700	69 000	142 200	1.407	97 100	239 300	128 700
1984						14 800	5700	14 800	5700	1.478	21 900	27 600	13 500
1985						13 000	5700	13 000	5700	1.551	20 200	25 900	11 500
1986						13 000	5700	13 000	5700	1.629	21 200	26 900	10 900
1987						13 000	5700	13 000	5700	1.711	22 200	27 900	10 300
1988						13 000	5700	13 000	5700	1.896	23 300	29 000	9700
1989						13 000	5700	13 000	5700	1.886	24 500	30 200	9200
1990						13 000	5700	13 000	5700	1.980	25 700	31 400	8700
1991						13 000	5700	13 000	5700	2.079	27 000	32 700	8200
1992						13 000	5700	13 000	5700	2.183	28 400	34 100	7800
1993						13 000		13 000		2.292	29 800	29 800	6200
TOTALS	11 800	6500	456 600	230 100	336 400	131 800	57 000	373 700	856 500	—	563 100	1 419 700	801 700

TABLE 15. TSP DOLLAR COSTS BY YEAR.

Calendar Year	RDT&E		Non-recurring Investment	Recurring Investment		Operation and Support		Total Annual Costs		Labor Costs Inflated		Total Costs	Discounted Costs 1976
	Labor	Material	Material	Material	Labor	Labor	Material	Labor	Material	5%			
1976													
1977	2000							2000		1.050	2100	2100	2000
1978	4500	7200						4500	7200	1.103	5000	12 200	10 600
1979	6000			49 400				6000	49 400	1.158	7000	56 400	44 400
1980			61 400	146 400	28 700			28 700	207 800	1.216	34 900	242 700	174 000
1981			178 500	146 400	86 100			86 100	324 900	1.276	109 900	434 800	283 500
1982			178 600	146 300	86 300			86 300	324 900	1.340	115 600	440 500	260 800
1983			178 500		86 100		7500	86 100	186 000	1.407	121 100	307 100	165 200
1984						18 500	7500	18 500	7500	1.478	27 300	34 800	17 000
1985						16 700	7500	16 700	7500	1.551	25 900	32 400	14 400
1986						16 700	7500	16 700	7500	1.629	27 200	34 700	14 000
1987						16 700	7500	16 700	7500	1.711	28 600	36 100	13 300
1988						16 700	7500	16 700	7500	1.796	30 000	37 500	12 500
1989						16 700	7500	16 700	7500	1.886	31 500	39 000	11 900
1990						16 700	7500	16 700	7500	1.980	33 100	40 600	11 200
1991						16 700	7500	16 700	7500	2.079	34 700	42 200	10 600
1992						16 700	7500	16 700	7500	2.183	36 500	44 000	10 000
1993						16 700		16 700		2.292	38 300	38 300	8000
TOTALS	12 500	7200	597 000	488 500	287 200	168 800	75 000	468 500	1 167 700	–	708 700	1 863 400	1 063 400

TABLE 16. "BOTTOMS UP" MODEL LIFE-CYCLE COSTS.

	Fiber Optics (dollars)	Coaxial (dollars)	TSP (dollars)
RDT&E	317 300	18 300	19 700
Investment (Nonrecurring)	456 100	456 600	597 000
Investment (Recurring)	461 600	566 500	775 700
Operation & Support	131 800	188 800	243 800
Total Life Cycle Cost (Current 1976 Dollars)	1 366 800	1 230 200	1 636 200

ELECTRICAL SUBSYSTEM WEIGHT ANALYSIS

The electrical subsystem weight-analysis phase of the cost-benefit evaluation is executed by parametrically increasing and decreasing the electrical subsystem weight of the basic A-7 aircraft to illustrate the effect upon weapon-system costs. For this analysis, the McDonnell Aircraft Company weights department generated weight impacts for the remainder (other subsystems) of the A-7 aircraft which would result from increasing or decreasing the size of the electrical subsystem. The cost-weight relationships are only applicable to the A-7 aircraft. A weight change in any category other than electrical will not have the same relationships as those for the electrical subsystem.

RDT&E COST SENSITIVITY TO WEIGHT

The sensitivity of RDT&E costs to electrical subsystem weight is shown in figure 4. Because the baseline cost is so large (1 016 988 million in constant 1977 dollars), the cost deltas for ±50 kg are proportional to the weight. The RDT&E cost delta is thus linear over this range of weights. The slope of the cost delta is $\$1.716 \times 10^5$ per kilogram.

PROCUREMENT COST SENSITIVITY TO WEIGHT

The procurement-cost delta was computed from the baseline cost for 800 aircraft of 4 260 198 millions of 1977 dollars. Performing the same type of calculations as discussed previously, yields the results shown in figure 5. The cost delta is again linear. The maximum delta is 47 million for the addition of 50 kilograms, while the reduction of 50 kilograms results in a negative delta of 47 millions.

It should be noted that the cost delta shown for procurement includes the cost delta shown for Flyaway and that all the spares are included in procurement costs. The slope of the procurement cost delta is $\$9.6 \times 10^5$ per kilogram.

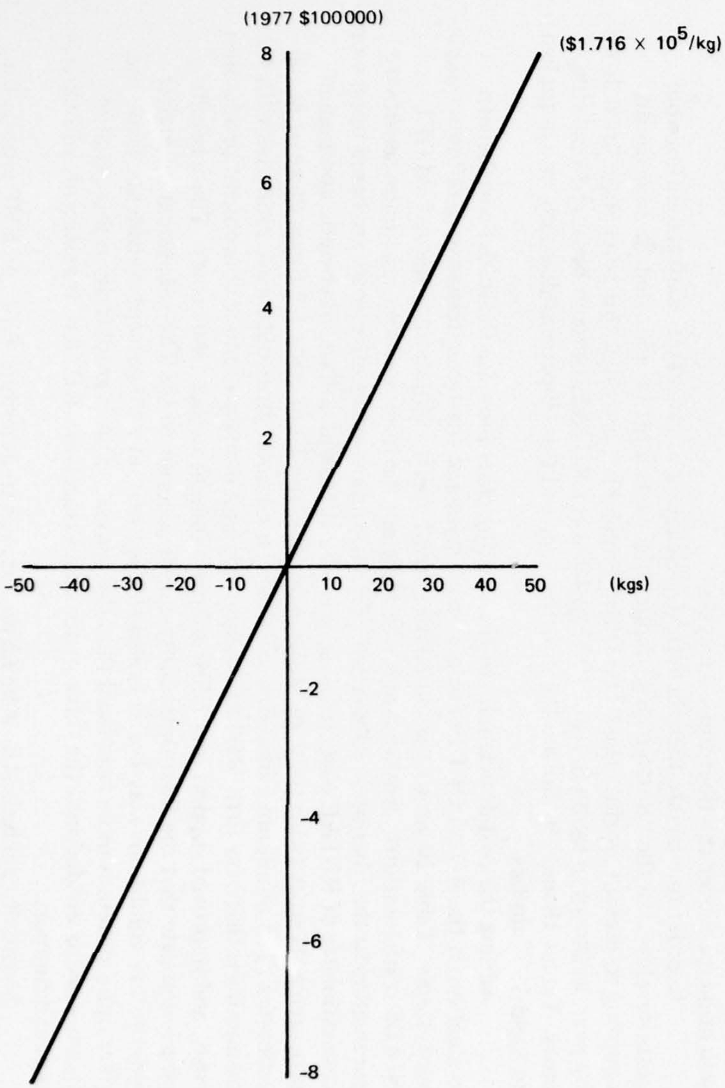

Figure 4. RDT&E cost deltas for electrical subsystem weight sensitivity.

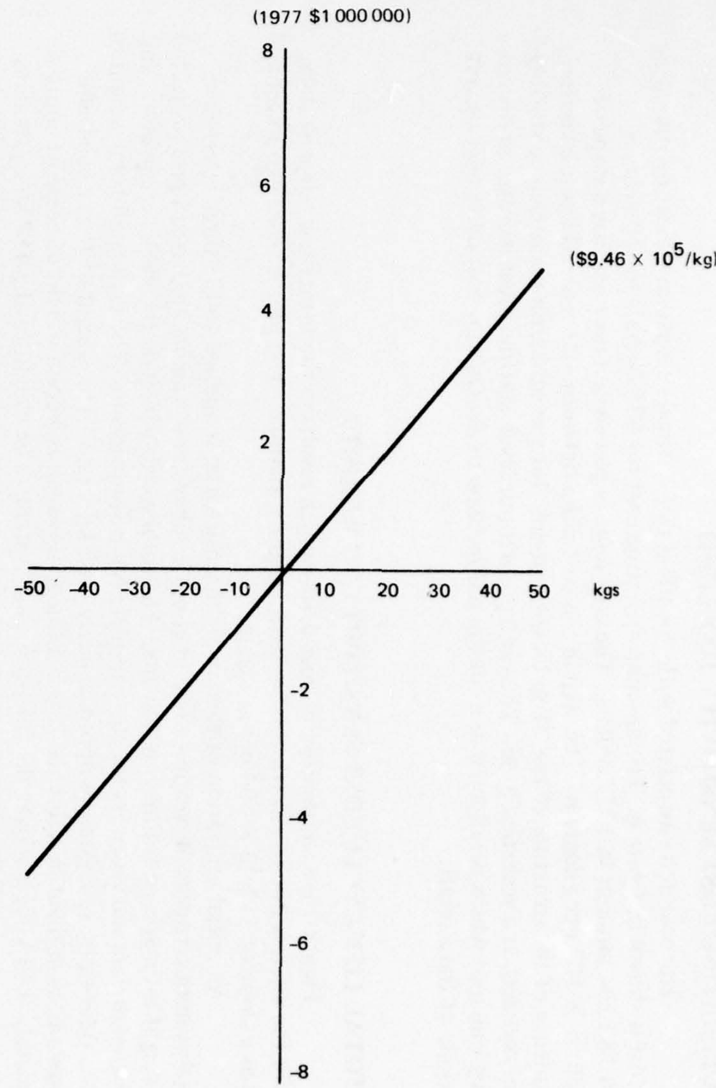

Figure 5. Procurement cost deltas for electrical subsystem weight sensitivity.

OPERATING COST SENSITIVITY TO WEIGHT

The cost delta associated with the effect of electrical subsystem weight on operating cost is shown in figure 6. The baseline operating cost for 675 aircraft for 10 years is 6 182 194 millions in 1977 dollars. The cost delta is piecewise linear and has a slope of $\$6.05 \times 10^5$ per kilogram. The step in the cost delta between −20 and −30 kgs is a consequence of the structure of the "Top Down" model. Integer squadron maintenance staffing is assumed, and realistically so. Thus at a given input level, staffing must increase or decrease by one unit which is reflected as a substantial increase or decrease of cost delta over the life cycle of the aircraft.

TOTAL LIFE-CYCLE COST SENSITIVITY TO WEIGHT

Figure 7 is a summation of cost deltas which results in the total life-cycle cost delta for the aircraft due to electrical subsystem weight variations. The plot is piecewise linear and has a slope of $\$17.22 \times 10^5$ per kilogram.

An initial utilization of these weight sensitivities is applied to the three alternative subsystem component weights. The fiber-optic subsystems weights are based upon projected weight estimates of future components. The total weights include the cable, connectors, and signal drivers and receivers for the complete NWDS subsystem. The estimated total weight of the fiber-optic subsystem is approximately 0.87 kilogram. The weight of the coaxial subsystem, as defined in reference 2, is 1.3 kilogram which is a delta weight increase of approximately 0.43 kilogram over the fiber-optic subsystem. The weight of the TSP subsystem, as designed by the McDonnell Aircraft Company is 1.91 kilogram which is a delta weight increase of approximately 1.04 kilogram over the fiber-optic subsystem. Table 17 gives the total system cost breakdown for the coaxial and TSP subsystems as a function of their respective delta weight increase over the fiber-optic subsystem.

In order to evaluate these benefit deficiencies or cost offsets with the differential costs developed in the "Bottoms Up" model, the costs must be allocated by year for discounting to present worth. The "Top Down" model has provided this percentage breakdown by year, as shown in figure 8, from 1977 to 1993 for RDT&E, procurement, and operating costs. Tables 18 and 19 allocate the costs by year and the 10-percent discount rate is applied to yield 1977 dollars.

Adding the cost deficiencies to the existing costs provides the initial cost/benefit evaluation of the A-7 ALOFT fiber-optic subsystem and the two alternative wire-interconnect subsystems. Table 20 shows the cumulative cost/benefit evaluation of the A-7 ALOFT N/WDS configurations. Also shown in the table are the minimum and maximum sensitivity parameters to the fiber-optic subsystem. The maximum cumulative costs are based upon worst-case estimates of RDT&E costs totaling over 750 thousand dollars, fiber-optic component procurements costs twice those of initial estimates, and labor costs 1.5 times those of initial estimates. The minimum cumulative costs are based upon most optimistic estimates with the assumptions that very little RDT&E is required, high demands reduce component production costs, and improved support and fabrication equipment reduce labor costs. These results clearly indicate that the fiber-optic subsystem is superior to the TSP subsystem no matter what future conditions may be. It is also evident that, at a 90-percent confidence level, the fiber-optic system is more beneficial than the coaxial. This is graphically represented in figure 9 and is divided into the three major cost categories: RDT&E, Investment, and Operation and Support.

Sensitivity analysis is now being undertaken to determine EMI and EMP criteria for the three alternatives as well as future systems designs and requirements. These results will be presented in the January final report.

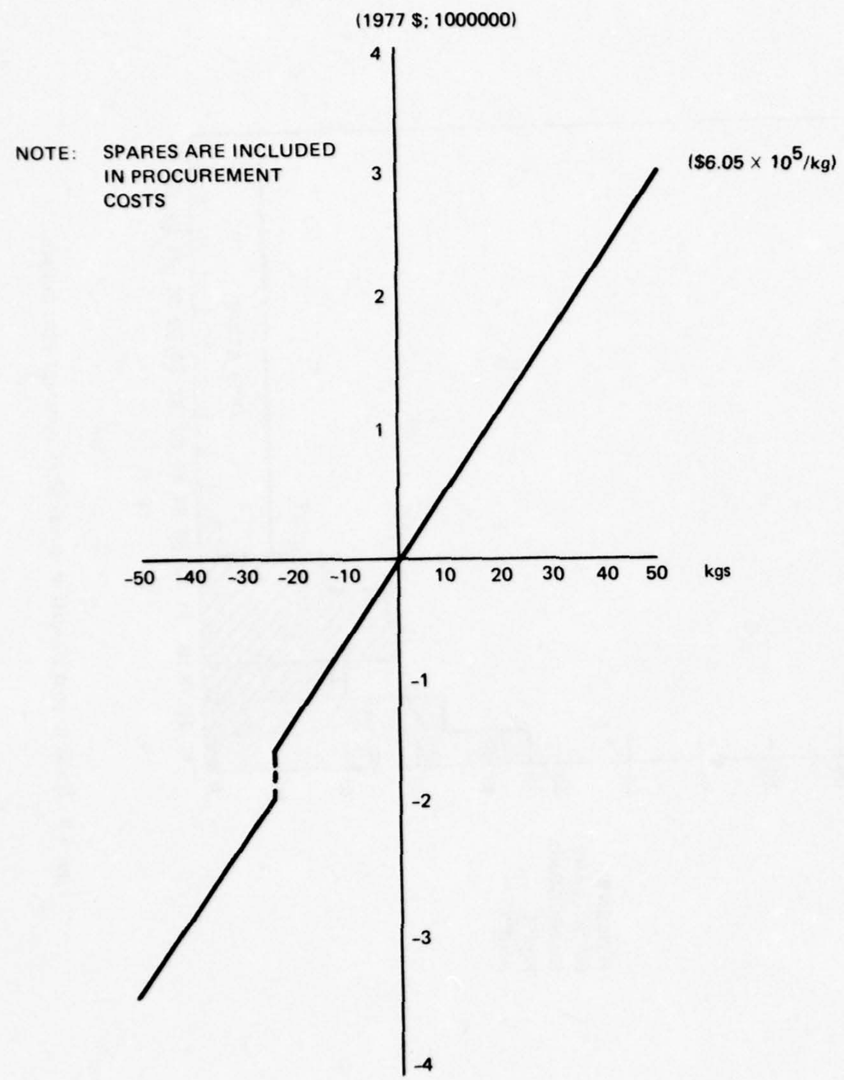

Figure 6. Operating cost deltas for electrical subsystem weight sensitivity.

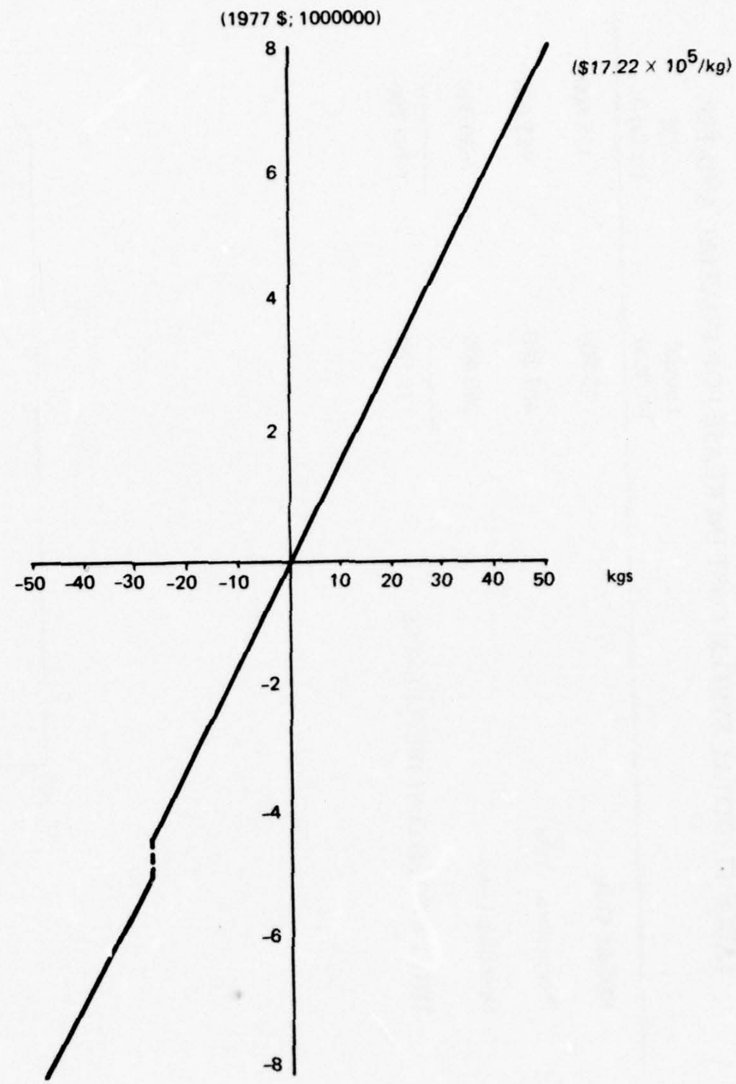

Figure 7. Total life-cycle cost deltas for electrical subsystem weight sensitivity.

TABLE 17. TOTAL SYSTEM COST INCREASE FOR COAXIAL AND TSP.

	Coaxial (dollars)	TSP (dollars)
RDT&E Costs	73 900	178 800
Procurement Costs	407 200	985 600
Operating Costs	260 400	630 300
TOTAL SYSTEM COST DIFFERENCES	741 500	1 794 700

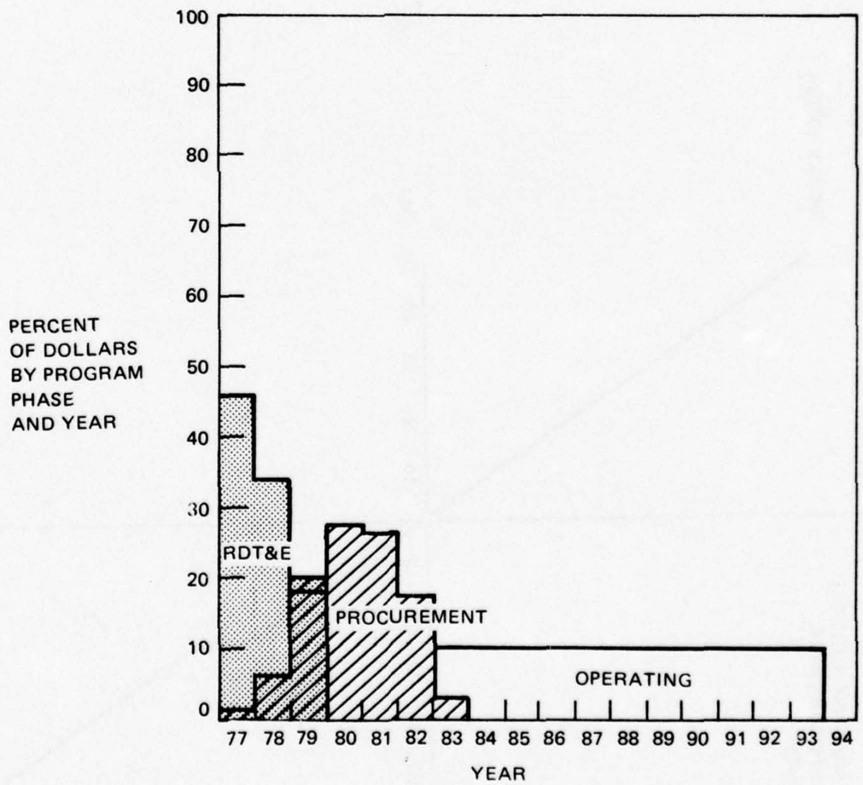

Figure 8. Relative cost allocation versus time, constant-year dollars.

TABLE 18. COAXIAL COST OFFSETS.

	R&D	Proc	O&S	Total	Discounted (dollars)
77	34 000	4100		38 100	38 100
78	25 100	24 400		49 500	47 200
79	14 800	73 300		88 100	76 400
80		114 000		114 000	89 800
81		105 900		105 900	75 900
82		73 300		73 300	47 800
83		12 200		12 200	7200
84			26 100	26 100	14 000
85			26 100	26 100	12 800
86			26 100	26 100	11 600
87			26 100	26 100	10 600
88			26 000	26 000	9700
89			26 000	26 000	8700
90			26 000	26 000	7900
91			26 000	26 000	7200
92			26 000	26 000	6500
93			26 000	26 000	5900
	73 900	407 200	260 400	741 500	477 300

TABLE 19. TSP COST OFFSETS.

	R&D	Proc	O&S	Total	Discounted (dollars)
77	82 200	9900		92 100	92 100
78	60 800	59 000		119 800	114 300
79	35 800	177 400		213 200	184 800
80		276 000		276 000	217 500
81		256 300		256 300	183 800
82		177 400		177 400	115 700
83		29 600		29 600	17 500
84			63 100	63 100	33 900
85			63 100	63 100	30 900
86			63 100	63 100	28 100
87			63 000	63 000	25 500
88			63 000	63 000	23 200
89			63 000	63 000	21 000
90			63 000	63 000	19 200
91			63 000	63 000	17 400
92			63 000	63 000	15 800
93			63 000	63 000	14 400
	178 800	985 600	630 300	1 794 700	1 063 000

TABLE 20. CUMULATIVE COST/BENEFIT EVALUATION OF A-7 ALOFT NWDS CONFIGURATIONS.

Estimated	Fiber Optics Min	Max	Coaxial	TSP
101 800	51 000	231 000	40 100	94 100
206 900	108 700	450 700	96 900	219 000
324 200	180 600	668 500	205 100	448 200
436 200	263 400	790 700	421 100	839 700
624 600	414 200	976 900	709 000	1 307 000
801 400	556 900	1 151 400	952 200	1 683 500
917 200	645 500	1 268 600	1 088 100	1 866 200
928 100	654 100	1 279 200	1 115 600	1 917 100
936 600	660 500	1 287 600	1 139 900	1 962 400
944 600	666 400	1 295 500	1 162 400	2 004 500
952 200	671 900	1 303 000	1 183 300	2 043 300
959 400	677 000	1 310 100	1 202 700	2 079 000
966 300	681 700	1 316 800	1 220 600	2 111 900
972 800	686 100	1 323 200	1 237 200	2 143 000
979 000	690 200	1 329 300	1 252 600	2 171 000
984 900	694 000	1 335 100	1 266 900	2 196 800
990 100	698 200	1 339 300	1 279 000	2 219 200

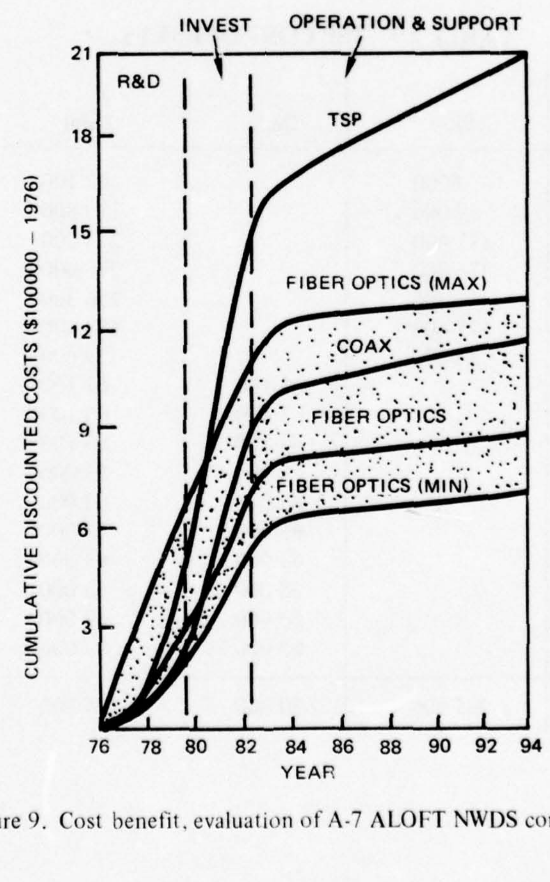

Figure 9. Cost benefit, evaluation of A-7 ALOFT NWDS configurations.

APPENDIX A:

FIBER-OPTIC COST ELEMENT DATA-COLLECTION SURVEY AND COST FACTORS.

Tables A-1 through A-19 present the fiber-optic cost-data elements and sources from whom these data were received.

TABLE A-1. TABULATION OF DIFFERENTIAL COST ELEMENTS.

Cost Category	Cost Element	Cost Element Description	Cost Factor
RDT&E	1.2.1.2	Design Engineering Cost	0.80
	1.2.1.3	Fabrication Cost (Test aircraft)	0.95 (labor) 1.05 (material)
	1.2.1.4	Development Test Costs	$100 000
	1.2.1.5	Test Support Costs	$100 000
	1.2.1.8	Test Equipment Costs	$100 000
Nonrecurring Investment	2.1.5	Initial Spares & Repair Parts	0.83
	2.1.6.3.2	Maintenance Training (Contractor)	$4000
	2.1.10	Peculiar Support Test Equipment	1.30
	2.2.2.2	Training Devices Costs	2.00
	2.2.2.3.2	Maintenance Training (Government)	$8000
	2.2.2.3.3	Instructor Training (Government)	$8000
Recurring Investment	3.1.1	Manufacturing Costs	0.80
	3.1.2.1	Purchased Equipment & Parts	0.83
	3.1.3	Sustaining Engineering	0.80
Operating & Support	4.2.1.1.1	Organizational Maintenance	0.80
	4.2.1.3	Support Equipment Maintenance	0.80
	4.2.2.3	Spare Parts & Repair Material	0.50
	4.2.2.4.1	Inventory Management Costs	1.60

TABLE A-2. DESIGN ENGINEERING COST (RDT&E) (1.2.1.2).

SOURCE:

Boeing Aerospace Co

Various engineering and technician personnel associated with the Boeing "flying experimental laboratory" working under the direction of Mr. Wallace Fields

McDonnell Aircraft Co

Telephone conversations with various aircraft manufacturing personnel

REMARKS:

Data gathered indicated that this factor would "probably" be about 0.80 but it could vary between 0.70 and 1.00. Engineering optimism dictates the value near 0.80. Fewer cable-location constraints with fiber-optic cable.

RANGE:

0.70 to 1.00

COST FACTOR:

0.80

TABLE A-3. FABRICATION COST (TEST AIRCRAFT) (RDT&E) (1.2.1.3).

SOURCE:

Same as element 1.2.1.2

REMARKS:

There is no way to calculate this cost factor. The general feeling among aircraft manufacturers was that there would be a "slight" cost savings until a production learning curve was established. Aircraft parts costs are estimated from current procurement costs with the application of an experience-curve technique to project to 1978. Labor costs are based upon McAIR learning-curve study with prototype fiber-optic equipment.

RANGE:

0.30 to 1.10 for labor

0.80 to 1.25 for material

COST FACTOR:

0.95 for labor

1.05 for material

TABLE A-4. DEVELOPMENT TEST COSTS (RDT&E) (1.2.1.4).

SOURCE:

Same as element 1.2.1.2

Telephone conversations with NAVAIR personnel

Telephone conversations with OPTEV personnel

REMARKS:

Testing seemed to be driven by the program budget. General comments range between $50 000 and $250 000.

RANGE:

$50 000 to $250 000

COST FACTOR:

$100 000.

TABLE A-5. TEST SUPPORT COSTS (RDT&E) (1.2.1.5).

SOURCE:

Same as element 1.2.1.4

REMARKS:

Same as element 1.2.1.4

RANGE:

Same as element 1.2.1.4

COST FACTOR:

$100 000.

TABLE A-6. TEST EQUIPMENT COSTS (RDT&E) (1.2.1.8).

SOURCE:

McDonnell Aircraft Co.

Boeing Aerospace Co.

(Glen E Miller – Research & Engineering Division)

(Engineers & Technicians involved with fiber optics)

(Quality-control engineers)

REMARKS:

The fiber-optic parameters that will require special test equipment have not been totally identified. Based upon previous experience, the value of $100 000 was determined to be a good place to start. The value can range from as low as $50 000 or as high as $250 000 and since there is no constraint on these limits they can change.

RANGE:

$50 000 to $250 000

COST FACTOR:

$100 000

TABLE A-7. INITIAL SPARES AND REPAIR PARTS COSTS (NON-RECURRING) (2.1.5).

SOURCE:

McDonnell Aircraft Co	DCA 600-60-1
Gnostic Concepts, Inc	Army Pamphlet 11-4
Air Force Avionics Laboratory	TRITAC LCC Model

REMARKS:

An assumption is made based on the above sources that initial spares can be computed at 10 percent of the procurement plus one spare for small buys less than 10 percent. This one-time cost is based on FY80 dollars and the procurement costs for wire-interconnect systems are estimated using an 11-percent inflation rate and the fiber-optic procurement costs are estimated using an 80-percent experience curve on projected demands and a technology-breakthrough estimation factor.

COMPUTATIONS:

Computations are based on large volume buys of quantities greater than 10 000 and cable lengths greater than 50 kilometres.

TABLE A-7. (Continued).

COAXIAL SUBSYSTEM COMPONENTS PER AIRCRAFT

	FY76 (dollars)	FY80 (dollars)		
55 metres of coaxial cable	0.50/m	0.75	=	$ 41.25
36 terminal connectors	1.68	2.55	=	91.80
26 bulkhead receptacles	1.68	2.55	=	66.30
5 pressure-bulkhead connectors	4.03	6.10	=	30.50
13 line drivers	1.85	2.80	=	105.30
13 line receivers	5.33	8.10	=	105.30
TOTAL COST PER AIRCRAFT =				$371.55

Thus, a 10-percent plus 1 initial spare cost would equal 37.15 + 22.85 = $60.00 per aircraft.

FIBER-OPTIC SUBSYSTEM COMPONENTS PER AIRCRAFT

	FY76 (dollars)	FY80 (dollars)		
55 metres of fiber-optic cable	0.0/m	0.50	=	$ 27.50
13 single-channel connectors	1.00	0.75	=	9.75
5 pressure-bulkhead connectors	1.50	1.00	=	5.00
1 multichannel connector	50.00	25.00	=	25.00
13 LED drivers	25.00	15.00	=	195.00
13 PIN receivers	10.00	5.00	=	65.00
TOTAL COST PER AIRCRAFT =				$327.25

Thus, a 10-percent plus 1 initial spare cost would equal 32.75 + 47.25 = $80.00 per aircraft.

The cost factor ratio for fiber-optic component spares versus coaxial component spares is 1.33.

However, for very large buys a 10-percent initial spare rate is all that is necessary, such that the cost factor may be as low as 0.85. Depending upon projected demands, the cost factor could be as high as 2.00.

RANGE:

0.85 to 2.00

COST FACTOR:

1.33

TABLE A-8. MAINTENANCE-TRAINING COSTS (NONRECURRING) (2.1.6.3.2).

SOURCE:

McDonnell Aircraft Co
NAVAIR program managers
NAVSEA program managers

REMARKS:

The only historical data were those supplied by McAIR. Contractor training costs appear to be collected at a higher level and aggregated in other cost centers. It is assumed that the contractor will train his personnel at a rate of ten students per course with one instructor and that the course will be one week in duration.

COST:

$4000

TABLE A-9. TEST-EQUIPMENT COSTS (NONRECURRING) (2.1.10).

SOURCE:

Same as 1.2.1.8

REMARKS:

The general feeling about fiber-optics test equipment is the cost would require an investment approximately 30 percent greater than coaxial test equipment. This value would be considerably less than 30 percent, but is it doubtful that it would be any greater than 30 percent.

RANGE

1.00 to 1.50

COST FACTOR:

1.30

TABLE A-10. TRAINING-DEVICES COSTS (2.2.2.2).

SOURCE:

Instructors and course coordinators at:

Electronics Technician School

Aviation Electrician Mate School

Aviation Electronics Technician School

- Basic
- Intermediate
- Advance

REMARKS:

This factor of 2.00 is based upon verbal information from the above sources. CNET was contacted but was unable to arrive at any cost figures.

It can be assumed that coaxial training devices can be generated routinely from existing training material. Fiber-optic training devices will require development from scratch.

RANGE:

1.50 to 3.00

COST FACTOR:

2:00

TABLE A-11. MAINTENANCE-TRAINING COSTS (NONRECURRING) (2.2.2.3.2)

SOURCE:

DCA Circular 600-60-1

REMARKS:

Use the tabulated values for:

10 students / 1 instructor / 1 week

After conversations with:

McDonnell Aircraft Co.

CNET

Various Navy Schools

It was decided to use half of the calculated value (originally $16 000) because of the assumed minimal level of training required.

COST:

$8000.

TABLE A-12. INSTRUCTOR-TRAINING COSTS (NONRECURRING) (2.2.2.3.3).

SOURCE:

Same as 2.2.2.3.2

REMARKS:

Same as 2.2.2.3.2

COST:

$8000

TABLE A-13. MANUFACTURING COSTS (RECURRING) (3.1.1).

SOURCE:

McDonnell Aircraft Co

REMARKS:

The only company that has investigated detailed manufacturing procedures.

RANGE:

0.70 to 1.25

COST FACTOR:

0.80

TABLE A-14. PURCHASED-EQUIPMENT AND PARTS COSTS (3.1.2.1).

SOURCE:

- NELC TD/435
- McDonnell Aircraft Co, informal Memo dtd 29 January 1976 from: RJ SOLOMON, Subj: Fiber-Optic Connector Installation
- Telephone conversations with fiber-optic manufacturers

REMARKS:

Coaxial (FY76 dollars) 231 200

Coaxial (FY80 dollars) (assume annual 10-percent inflation, plus 1-percent strategic)

Commodity rate increase: 316 300

Fiber Optics (FY80 dollars) 262 200

FACTOR = 262 200 ÷ 316 300 = 0.83

COAXIAL (FY76)

Type of Component	Part No	Total Req	Unit Cost (dollars)	Total Cost (dollars)
1. Single cables	RG-316	44.8 km	0.418/m	18 700
2. Single connector				
(36) a. Single-channel bulkhead	50-622-9188-31	28 800	1.68	48 400
(26) ————————	50-645-4576-31	20 800	1.68	35 000
(5) b. Single-channel pressure bulkhead	50-675-7000-31	4000	3.43	13 700
(26) Printed circuit		20 800	1.96	40 800
(13) 3. Signal Driver	SN54S140	10 400	1.85	19 200
(13) 4. Signal Receiver	SN54S132	10 400	5.33	55 400
				231 200

FY80 = 231 200 × 1.368 = 316 300

TABLE A-14. (Continued).

COAXIAL (FY80)

Type of Component	Part No	Total Req	Unit Cost (dollars)	Total Cost (dollars)
1. Single cables	VALTEC Type	44.8 km	0.50/m	22 400
2. Single connector				
a. Single-channel bulkhead	NELC dev (13)	10 400	0.75	7800
b. Single-channel pressure bulkhead	NELC dev (5)	4000	1.00	4000
c. Multichannel pressure bulkhead	NELC dev (1)	800	25.00	20 000
3. Signal Driver	NELC dev (13)	10 400	15.00	156 000
4. Signal Receiver	NELC dev	10 400	5.00	52 000
				262 200

RANGE:

0.5 to 2.50

COST FACTOR:

0.83

TABLE A-15. SUSTAINING-ENGINEERING COSTS (RECURRING) (3.1.3).

SOURCE:

Same as 1.2.1.2

REMARKS:

Same as 1.2.1.2

RANGE:

0.70 to 1.00

COST FACTOR:

0.80

TABLE A-16. MAINTENANCE-PERSONNEL COSTS (4.2.1.1.1).

SOURCE:

Boeing Aerospace Co.

(Glen E Miller, Research & Engineering Division)

NARF, San Diego

Maintenance personnel at:

NORIS, San Diego

Miramar Air Station, San Diego

REMARKS:

Reliability data for fiber optics are non-existent but the fiber-optic applications in the Air Force Minuteman program have proven quite reliable. Maintenance personnel consider the standard coaxial/pin connector a large maintenance problem and, therefore, the expectations for fiber-optic connectors to reduce this problem are high. Maintenance could be reduced as much as 30 percent (without connector-pin problems).

RANGE:

0.70 to 1.00

COST FACTOR:

0.80

TABLE A-17. SUPPORT-EQUIPMENT MAINTENANCE COSTS (4.2.1.3).

SOURCE:

Same as 1.2.1.2

REMARKS:

Same as 1.2.1.2

RANGE:

0.70 to 1.00

COST FACTOR:

0.80

TABLE A-18. SPARE-PARTS AND REPAIR-MATERIAL COSTS (4.2.2.3).

SOURCE:

See cost element 2.1.5

REMARKS:

Assumptions:

10-percent spare parts

FY85 dollars

10-percent annual inflation for coaxial components plus 1 percent for strategic commodities

80-percent fiber-optics manufacturing experience curve

Only 84 percent of the aircraft are considered to be in an operational status thus costs are 10-percent of total acquisition times 84 percent = $0.10 \times 0.84 \times$ Acquisition Cost.

COMPUTATIONS:

Fiber-optic component costs will be approximately the same estimated values as they were for FY80 or $327.25 per aircraft.

Coaxial component costs will increase due to the 10-percent annual inflation rate and the utilization of strategic resources up to $650.00 per aircraft.

RANGE:

0.4 to 2.00

COST FACTOR:

0.50

TABLE A-19. INVENTORY-MANAGEMENT COSTS (4.2.2.4.1).

SOURCE:

TRI-TAC inventory-management equation

REMARKS:

Five new coaxial items

Eight new fiber-optic items

All costs as weighted average

(This is a good approximation since the factor is the same in the second decimal place for both weighted average and values less than $2500/FSN.)

Cost Elements	Value	Units
Number of new FSN items		Items
FSN item 1st-year cost	(from chart below)	$/item
FSN item recurring cost	(from chart below)	$/item/year
Number of years per life cycle	10	Years

INVENTORY LINE-ITEM MANAGEMENT COSTS

FSN Value (dollars)	Introduction Costs (dollars)	First Year Cost[1] (dollars)	Annual Recurring Costs (dollars)
Over 25 000	680	1070	720
10 000 to 24 999	530	770	420
2500 to 9999	450	580	130
Under 2500	480	460	110
Weighted average	480	510	160

[1]Includes introduction cost

COST FACTOR:

1.60

APPENDIX B:

HARDWARE FABRICATION AND INSTALLATION TIME AND MOTION STUDIES.

McAIR ANALYSIS

The McAir Manufacturing Methods Engineering Department has completed an estimate of the shop assembly time for the fabrication and installation of the NWDS configurations. The results of the study are used directly in the execution of the "Bottom's Up" model. The operations described in table B-1 are self-explanatory. As expected, the larger and longer harness, with four branches, requires substantially more time to complete than the simple harness with two connectors. Figure B-1 is the projected TSP cable-fabrication progress curve for the A-7 ALOFT aircraft. The target of 5.67 manhours per fabrication occurs at ship number 124 and follows a gradual 95-percent slope beginning at 8.10 manhours for ship number 1. The low number of manhours for ship number 1, and the gradual slope, are due principally to the experience McAIR has gained working with TSP.

TABLE B-1. HARNESS SHOP ASSEMBLY TIME.

	Harness A (hours)	Harness B (hours)
Mark	.132	.077
Cut	.101	.056
Thermofit install (TFI)	.054	.029
Ferrules (FERR)	.288	.135
Crimp pins (CIP)	.140	.074
Sequence (SEQ)	.026	.016
Check in (C/I)	.040	.025
First solder (termination) (F/S)	.562	.273
Wire harness board (WHB)	2.365	.756
Ferrules (FERR)	.367	.154
	4.075	1.595

4.075
1.595

5.67 MHR's has 15% P&F included

P&F = Personal and Fatigue

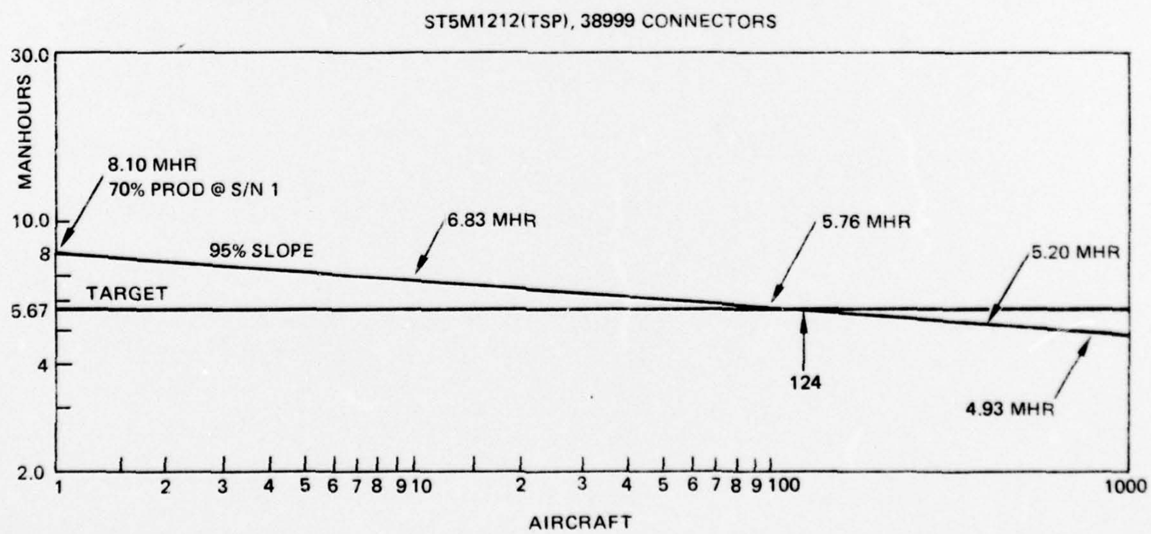

Figure B-1. Projected TSP-cable fabrication progress curve A-7 ALOFT program, ships 1 through 1000.

Fabrication analysis included the time required to cut, identify, make solder connections, inspect, and check out each of the coaxial cables. The average time per cable was approximately 13 minutes with a total for the coaxial-interface system fabrication of 4.061 manhours. This total includes allowance of 15 percent for personal time and fatigue. Table B-2 gives a detailed breakdown for each task on each cable.

Fabrication time for fiber optics was slightly longer than coaxial but shorter than TSP. However, this time of 5.039 (table B-3) manhours is based upon little personnel experience in fiber-optic fabrication. Figure B-2 projects fiber-optic fabrication as more experience is gained. The 76-percent and 85-percent slopes are based upon McAIR knowledge of personnel learning a new technique. Initial learning is very high for the first ten aircraft then the gradual repetition of the assembly process is slightly less. For an 800-ship production, the assembly time is 3.624 manhours.

The installation tasks included unbag and layout, routing, clamping, tying, installation of bulkhead adapters, hook-up of connectors, installation and sealing of feedthroughs, inspection, and checkout. The total installation time required for the coaxial cables was 4.137 hours including 15 percent for personal time and fatigue. The projected productivity of 20 percent for the first aircraft gives an estimate of 20.685 manhours for the RG-316 coaxial-interface system installation. The breakdown of each task is given in table B-4, and figure B-3 gives the installation progress curve for ships 1 through 400. The harness installation for TSP is approximately the same as for the A-7 ALOFT coaxial configuration.

The total installation time required for the fiber optics is 3.859 hours including 15 percent for personal time, fatigue, and delay. The projected productivity of 20 percent for the first aircraft gives an estimate of 19.295 manhours for the fiber-optic-interface system installation. These figures are somewhat less than those projected for the TG-316/U interface system installation. Table B-5 is a cable-by-cable listing of all installation activities and figure B-4 is a projected progress curve for installation of fiber optics on the A-7 ALOFT program for ships 1 through 1000.

TABLE B-2. COAXIAL-CABLE FABRICATION TIME, A-7 ALOFT PROGRAM.

RG 316/U Coaxial Cables	Length (cm)	Cut & ID	Conn	MHR Tgt per Conn	Conn Tgt	Insp	Check-out	MHR/ Coaxial
1 FT3067-14A	404	.021	2	.0787	.1574	.020	.030	.2284
2 FT3067-15A	404	.021	2	.0787	.1574	.020	.030	.2284
3 FT3067-16A	531	.024	2	.0787	.1574	.020	.030	.2314
4 FT3067-17A	531	.024	2	.0787	.1574	.020	.030	.2314
5 FT3067-18A	531	.024	2	.0787	.1574	.020	.030	.2314
6 FT3067-19A	531	.024	2	.0787	.1574	.020	.030	.2314
7 FT3067-20A	531	.024	2	.0787	.1574	.020	.030	.2314
8 FT3067-23A	231	.016	2	.0787	.1574	.020	.030	.2234
9 FT3067-24A	231	.016	2	.0787	.1574	.020	.030	.2234
10 FT3067-25A	175	.015	2	.0787	.1574	.020	.030	.2224
11 FT3067-26A	175	.015	2	.0787	.1574	.020	.030	.2224
12 FT3067-27A	236	.017	2	.0787	.1574	.020	.030	.2244
13 FT3067-28A	236	.017	2	.0787	.1574	.020	.030	.2244
14 FT3067-16B	158	.014	2	.0787	.1574	.020	.030	.2214
15 FT3067-17B	158	.014	2	.0787	.1574	.020	.030	.2214
16 FT3067-18B	158	.014	2	.0787	.1574	.020	.030	.2214
17 FT3067-19B	158	.014	2	.0787	.1574	.020	.030	.2214
18 FT3067-20B	158	.014	2	.0787	.1574	.020	.030	.2214
SUB-TOTALS		.328 HRS	36		2.833 HRS	.360 HRS	.540 HRS	4.061 MHRS

4.061 MHR Tgt has 15% P&F included

TABLE B-3. PROJECTED FIBER-OPTIC CABLE FABRICATION TIME, A-7 ALOFT PROGRAM.

Fiber Optic Cables	Length (cm)	Cut & ID	Panel Conn	MHRs	ST Conn	MHR Tgt per Conn	MHRs	Insp	Check-out	MHR/ F/O
FT3067-14A-F/O	404	.021	1	.1113	1	.1106	.1106	.020	.020	.2829
FT3067-15A-F/O	404	.021	1	.1113	1	.1106	.1106	.020	.020	.2829
FT3067-16A-F/O	531	.024	1	.1113	1	.1106	.1106	.020	.020	.2859
FT3067-17A-F/O	531	.024	1	.1113	1	.1106	.1106	.020	.020	.2859
FT3067-18A-F/O	531	.024	1	.1113	1	.1106	.1106	.020	.020	.2859
FT3067-19A-F/O	531	.024	1	.1113	1	.1106	.1106	.020	.020	.2859
FT3067-20A-F/O	531	.024	1	.1113	1	.1106	.1106	.020	.020	.2859
FT3067-23A-F/O	231	.016	1	.1113	1	.1106	.1106	.020	.020	.2779
FT3067-24A-F/O	231	.016	1	.1113	1	.1106	.1106	.020	.020	.2779
FT3067-25A-F/O	175	.015	1	.1113	1	.1106	.1106	.020	.020	.2769
FT3067-26A-F/O	175	.015	1	.1113	1	.1106	.1106	.020	.020	.2769
FT3067-27A-F/O	236	.017	1	.1113	1	.1106	.1106	.020	.020	.2789
FT3067-28A-F/O	236	.017	1	.1113	1	.1106	.1106	.020	.020	.2789
FT3067-16B-F/O	158	.014			2	.1106	.2212	.020	.020	.2752
FT3067-17B-F/O	158	.014			2	.1106	.2212	.020	.020	.2752
FT3067-18B-F/O	158	.014			2	.1106	.2212	.020	.020	.2752
FT3067-19B-F/O	158	.014			2	.1106	.2212	.020	.020	.2752
FT3067-20B-F/O	158	.014			2	.1106	.2212	.020	.020	.2752
SUBTOTALS		.328 HRS	13	1.4469 HRS	23		2.5438 HRS	.360 HRS	.360 HRS	5.039 MHRS

5.039 MHR Tgt has 15% P&F included

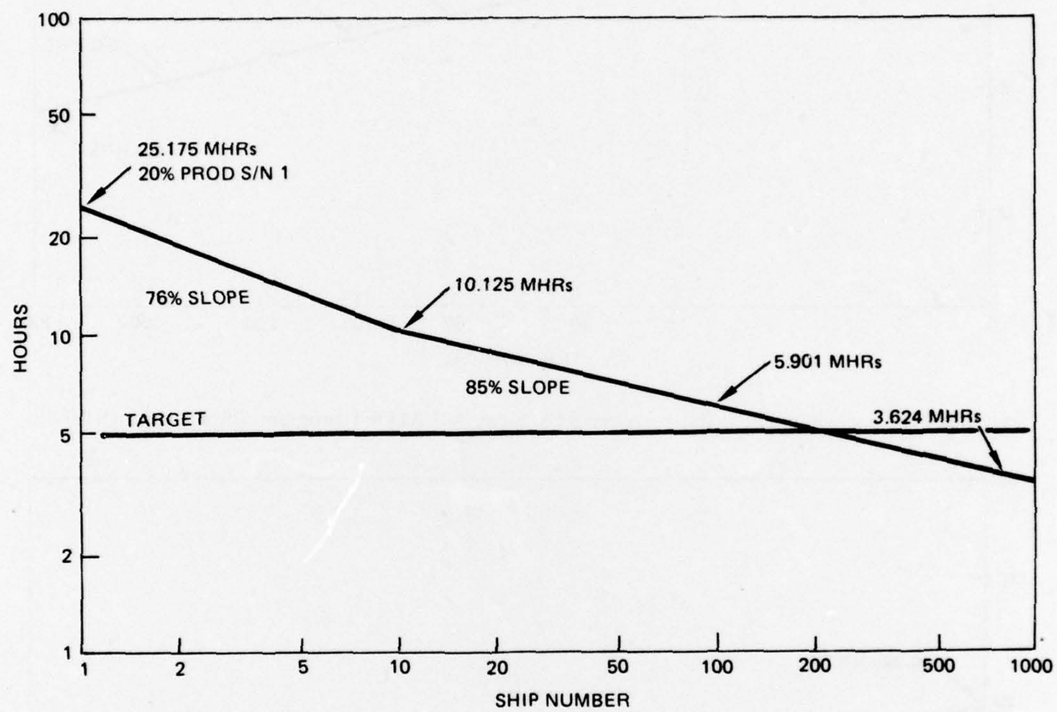

Figure B-2. Projected fiber-optic cable fabrication progress curve, A-7 ALOFT program, ships 1 through 1000.

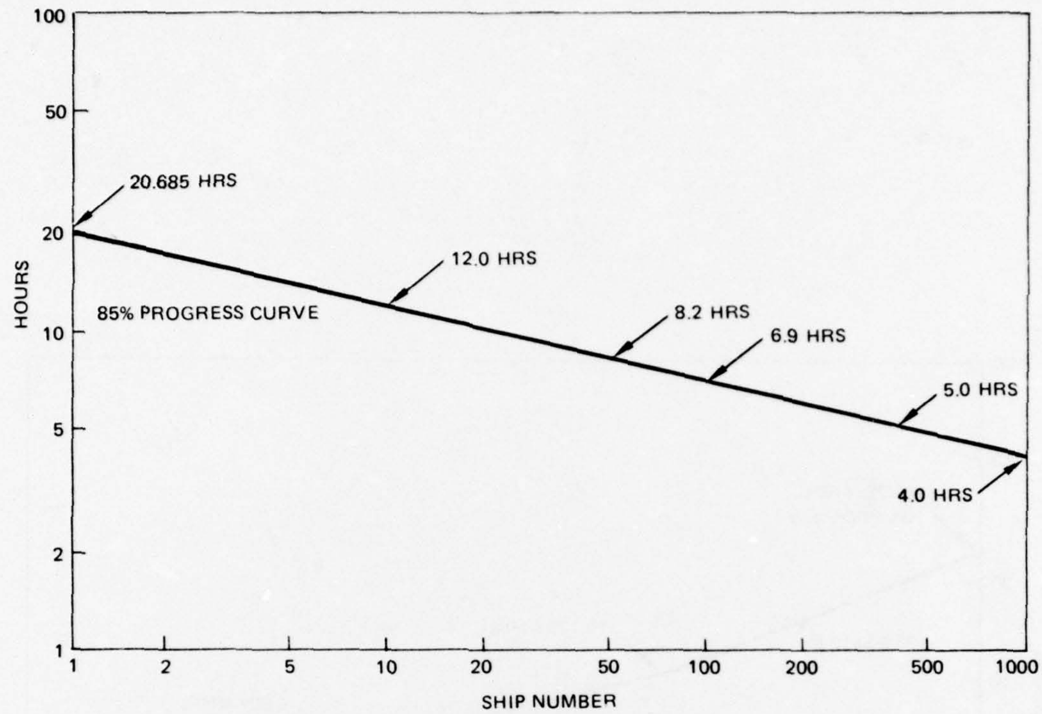

Figure B-3. Coaxial and TSP installation progress curve, A-7 ALOFT program, ships 1 through 1000.

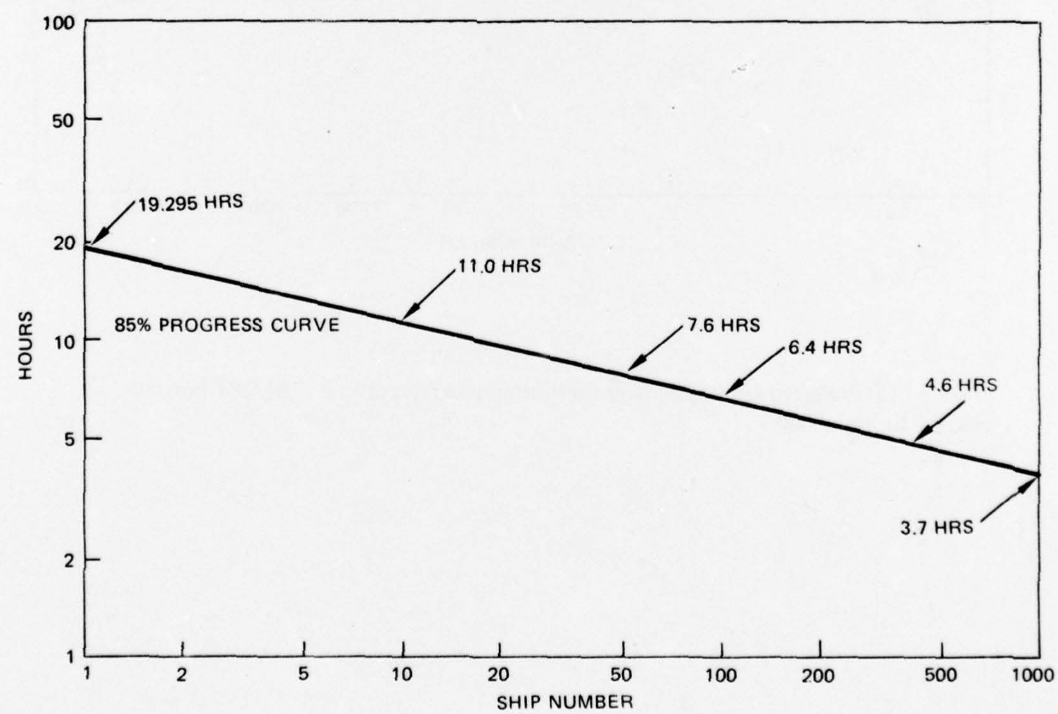

Figure B-4. Projected fiber-optic cable installation progress curve, A-7 ALOFT program, ships 1 through 1000.

TABLE B-4. RG 316/U COAXIAL INSTALLATION TIME, A-7 ALOFT PROGRAM.

Work Description	Length (cm)	Unbag & Layout	Route	Clamp	Stringtie	Inst Blkhd Adapter	Hook-up Connectors	Feedthrus & Seal	Inspect	Checkout
Standard Data Allowance (hours)		.030/ASSY	.005/FT	.018/CLP	.008/TIE	.025/ADAPT	.005/CONN	.100/F.T.	.020/CABLE	.060/CABLE
RG 316 Coaxial Cables						Extended Allowances				
Equivalent to -14A Fiber Optic	404		.015	.054	.048	N/A	.005		.020	.060
Equivalent to -15A Fiber Optic	404					N/A	.005		.020	.060
Equivalent to -16A Fiber Optic	404					N/A	.005		.020	▽ .030
Equivalent to -17A Fiber Optic	531					N/A	.005	.200	.020	▽ .030
Equivalent to -18A Fiber Optic	531		.075	.270	.240	N/A	.005		.020	▽ .030
Equivalent to -19A Fiber Optic	531					N/A	.005		.020	▽ .030
Equivalent to -20A Fiber Optic	531	.030				N/A	.005		.020	▽ .030
Equivalent to -23A Fiber Optic	231		.040	.144	.128	N/A	.005	N/A	.020	.060
Equivalent to -24A Fiber Optic	231					N/A	.005	N/A	.020	.060
Equivalent to -25A Fiber Optic	175		.030	.090	.096	N/A	.005	N/A	.020	.060
Equivalent to -26A Fiber Optic	175					N/A	.005	N/A	.020	.060
Equivalent to -27A Fiber Optic	236		.040	.144	.128	N/A	.005	N/A	.020	.060
Equivalent to -28A Fiber Optic	236					N/A	.005	N/A	.020	.060
Equivalent to -16B Fiber Optic	158	.030	.025			.025	.010	N/A	.020	▽ .030
Equivalent to -17B Fiber Optic	158	.030	.025			.025	.010	N/A	.020	▽ .030
Equivalent to -18B Fiber Optic	158	.030	.025	.090	.080	.025	.010	N/A	.020	▽ .030
Equivalent to -19B Fiber Optic	158	.030	.025			.025	.010	N/A	.020	▽ .030
Equivalent to -20B Fiber Optic	158	.030	.025			.025	.010	N/A	.020	▽ .030
	SUB TOTALS	.180	.325	.792	.720	.125	.115	.200	.360	.780

NOTE: The above standard data allowances are based on McAIR past experience installing RG-316 coaxial cables.

TOTAL: 3.597 hrs, plus 15% personal, fatigue & delay = 4.137 allowed hrs; projected 20% productivity first article = 20.685 estimated manhour expenditure to install RG-316 coaxial cables, A-7 ALOFT.

▽ Fiber-optic/coaxial cables will not be disconnected at the seat bulkhead adapter during checkout.

TABLE B-5. FIBER-OPTIC INSTALLATION TIME, A-7 ALOFT PROGRAM.

Work Description	Length (cm)	Unbag & Layout	Route	Clamp	Stringtie	Inst Blkhd Adapter	Hook-up Connectors	Feedthrus & Seal	Inspect	Checkout
Standard Data Allowance (hours)		.030/ASSY	.005/FT	.018/CLP	.008/TIE	.015/ADAPT	.008/CONN	.100/FT	.020/CABLE	.040/CABLE
Fiber Optic Cables										
FT3067-14A-F/O	404		.015	.054	.048	N/A	.008		.020	.040
FT3067-15A-F/O	404					N/A	.008		.020	.040
FT3067-16A-F/O	404					N/A	.008		.020	.020
FT3067-17A-F/O	404					N/A	.008	.200	.020	.020
FT3067-18A-F/O	531		.075	.270	.240	N/A	.008		.020	.020
FT3067-19A-F/O	531					N/A	.008		.020	.020
FT3067-20A-F/O	531	.030				N/A	.008		.020	.020
FT3067-23A-F/O	231		.040	.144	.128	N/A	.008	N/A	.020	.040
FT3067-24A-F/O	231					N/A	.008	N/A	.020	.040
FT3067-25A-F/O	175		.030	.090	.096	N/A	.008	N/A	.020	.020
FT3067-26A-F/O	175					N/A	.008	N/A	.020	.040
FT3067-27A-F/O	236		.040	.144	.128	N/A	.008	N/A	.020	.040
FT3067-28A-F/O	236					N/A	.008	N/A	.020	.040
FT3067-16B-F/O	158	.030	.025			.015	.016	N/A	.020	.020
FT3067-17B-F/O	158	.020	.015			.015	.016	N/A	.020	.020
FT3067-18B-F/O	158	.030	.015	.090	.080	.015	.016	N/A	.020	.020
FT3067-19B-F/O	158	.030	.025			.015	.016	N/A	.020	.020
FT3067-20B-F/O	158	.030	.025			.015	.016	N/A	.020	.020
SUB TOTALS		.180	1.325	.992	.720	.075	.184	.200	.360	.510

NOTE: The above extended allowances were developed based on the assumption that McAIR fabrication and installation techniques would be utilized. Examples: Joint routing, clamping, stringties etc.

TOTAL = 3.356 hrs, plus 15% personal, fatigue & delay = 3.859 allowed hrs; projected 20% productivity first article = 19.295 estimated manhour expenditure to install fiber-optic cables, A-7 ALOFT.

HARDWARE COST SUMMARY

COAXIAL

The costs for the hardware components for the coaxial interface system were determined by the McDonnell Aircraft Company purchasing department.

Quotations for the RG-316/U coaxial cable were obtained from two vendors in quantities of 100, 500, 1000, and 2500 metres. The costs per one hundred metres ranged between $38.65 and $57.70 depending upon the quantity of buy. A detailed breakdown of these costs is given in table B-6. The figures shown are budgetary estimates by the vendors.

TABLE B-6. RG-316/U COAXIAL-CABLE COSTS (DOLLARS PER 100 METRES).

BUY (METRES)	100	500	1000	2500
VENDOR A	57.70	50.51	46.96	44.89
VENDOR B	----	45.88	45.88	38.65
AVERAGE	57.70	48.20	46.43	41.77

NOTE: Estimate cost increase per year of 10 percent.

Quotes were obtained for the terminal connectors (50-622-9188-31), bulkhead receptacles (50-645-4576-31), and pressure-bulkhead connectors (50-675-7000-31). Data were obtained for these components for quantities of 100, 1000, and 10 000 in terms of cost and delivery schedule. See table B-7 for details.

The unit costs of the line drivers (Type SN54S140) and line receivers (Type SN54S132) were obtained for quantities of 100, 1000, and 10 000 and are presented in table B-8.

TABLE B-7. CONNECTOR PRICE VS QUANTITY, VENDOR DATA AS OF JAN 20, 1976.

Nomenclature	Selectro P/N	Quantity	Unit Price	Delivery
Terminal Connectors	50-622-9188-31	100	$2.79	4 Weeks ARO
		1000	1.98	4 Weeks ARO
		10 000	1.68	4 Weeks ARO
Bulkhead Receptacles	50-645-4576-31	100	2.79	4 to 6 Weeks ARO
		1000	1.98	4 to 6 Weeks ARO
		10 000	1.68	4 to 6 Weeks ARO
PC Card to Coaxial Connector	50-651-0000	100	3.26	4 to 6 Weeks ARO
		1000	2.31	4 to 6 Weeks ARO
		10 000	1.96	4 to 6 Weeks ARO
Pressure Bulkhead Connectors	50-675-7000-31	100	5.68	4 to 6 Weeks ARO
		1000	4.03	4 to 6 Weeks ARO
		10 000	3.43	4 to 6 Weeks ARO

NOTE: — Gold-plated items are subject to a surcharge of 0.1 percent for each dollar per troy ounce increase above 70 dollars per troy ounce published average gold price for the calendar month preceding date of invoice.

TABLE B-8. LINE DRIVER AND RECEIVER COSTS.

Nomenclature	Number	Quantity	Unit Price (dollars)
Line Driver	Texas Inst	100	5.58
	SN54S140J	1000	2.66
		10 000	1.85
Line Receiver	Texas Inst	100	12.99
	SN54S132J	1000	8.66
		10 000	5.33

TSP

The TSP configuration chosen for the A-7 ALOFT aircraft follows closely the wiring methods used by McAIR. Specifically, the fifteen wires are harnessed and appropriate multipin connectors are used for termination on all adapter boxes and at the bulkhead feedthrough. The TSP selected is a precision extruded cable designed to maintain a characteristic impedance within ±5.8 percent. The cable is identified in the McAIR Standard Parts Manual as ST5M1212-002 and is widely used for data transfer on the F-15 aircraft. A detailed breakdown of these costs is given in table B-9.

The connectors chosen are similarly widely used by McAIR and are manufactured by Bendix Electrical Components Division, Sidney, New York. Table B-10 is a list of the six connector types (3 mating pairs) used for the A-7 ALOFT TSP configuration along with unit costs for quantity buys of more than 100 units. The unit costs for the signal drivers and receivers (table B-11) are also for quantity buys of more than 100 units.

TABLE B-9. TSP ST5M1212-002 COSTS.

Quantity (metres)	Cost Per Metre (dollars)
Zero to 3000	0.82
3000 to 7600	0.74
15 000	0.71

TABLE B-10. CONNECTORS USED IN THE A-7 ALOFT TSP CONFIGURATION.

Receptacles with Pins	Small Quantity (dollars)
MS27499T14F35P	14.80
MS27499T8F35P	12.26
MS27474T12F35P	17.28
Plugs with Sockets	
MS27473T14F35S	17.46
MS27473T8F35S	11.61
MS27473T12F35S	14.73

Bendix Electrical Components Division, Sidney, NY

TABLE B-11. SIGNAL DRIVERS/RECEIVERS.

	Costs 100 or more (dollars)
Fairchild 55107 Receiver	3.38
Fairchild 55109 Driver	3.55

MATERIALS COST PROJECTION

The materials used in the coaxial cable (RG-316/U) and Twisted Shielded-Pair (ST5M1212-002) being studied are: copper, silver, steel, fluoronated ethylene propylene, (FEP), and polytetrafluoroethylene (PTFE). The cost per linear metre of cable of each of these materials is broken down in table B-12 and summed to give the total cost of materials per metre of approximately 20 cents. The data used to make this determination were extracted from McAIR materials engineering in January 1976, and from the coaxial specification. Recent vendor budgetary quotes for RG-316/U coaxial cable and ST5M1212-002 TSP to McDonnell Aircraft are between 40 cents and 60 cents per metre, depending upon quantity of buy. From this, it can be seen that the raw materials cost is between 1/3 to 1/2 of the cable cost to the aircraft manufacturer. The highest cost contribution is made by the silver plating on the inner and outer conductors, making up approximately 72 percent of the total material cost.

The coaxial connectors used for the study (Amphenol 31-369 and 31-371) are constructed of brass with a silver coat of approximately 2.5 μm. The contacts in the connector are copper with a 1.27-μm gold flash coating.

TABLE B-12. CABLE MATERIAL COSTS.

Component	Material Type	Cost (cc) (dollars)	Linear Metre (no of cc)	Cost (linear metre) (dollars)	Percent Total Cost
Jacket	FEP	.024	699	.017	8
Outer Conductor	Copper Braid	.012	1.338	.016	64
	Silver Plate	1.450	.081	.118	
Cable Core	PTFE	.015	1.621	.024	11.5
Inner Conductor	Steel	.005	.096	.00048	
	Silver Plate	1.450	.023	.033	16.2
	Copper Plate	.124	.021	.0003	
Total (metre)				.209	

COST BREAKDOWN

Each of the materials is discussed in following paragraphs with respect to projected cost, supply and demand, and contingencies.

IRON

The average unit price for iron in 1968 was 1.5 cent per kilogram and the projected price for the year 2000 (in 1968 dollars) is 1.8 cent per kilogram. This represents an average unit price increase of 0.625 percent per year. At present, approximately 30 percent of our domestic iron requirements and, essentially, all of our requirements for chromium, columbium, tantalum, and manganese are met from foreign sources. The cost of the electrical steel in the cable being studied contributes only 0.2 percent of the total cost and, for this reason, the cost increase in material will not be a significant factor.

COPPER

Copper is a significant percentage of the materials cost for the coaxial cable (8.1 percent) and the major metal used in the connector shells.

Projections show that copper prices will increase 77 percent in the period 1968 to 2000; ie, an average yearly price increase of 2.4 percent. The major reasons for increasing prices are the requirements imposed on the copper smelting industries to meet pollution standards, and the increasing cost of energy. The 14 copper smelters in the United States have spent between $700 and $800 million for major pollution abatement facilities. The problem is that the expenditure of funds to meet pollution standards diverts funds that could otherwise be spent for necessary expansion of production capacity. Projections by McGraw-Hill of total capital requirements for all US business through 1988 show a 73-percent increase and an increase of 199 percent for the nonferrous metals industry. United States smelters currently produce 90 percent of the copper used by this country with 10 percent imported.

Continuing environmental requirements could cause prices to increase to the point where foreign imports might be more attractive. However, this approach has its problems since cartel-like action (likely to come from the intergovernmental council of copper exporting countries) by Chile, Peru, Zambia, and Zaire, which control 53 percent of the world's copper exports, could also increase prices. Supply of copper in the United States is no problem since we have 22.5 percent of the world's reserves, enough to last 40 years at current production rates, and should still be no problem with the anticipated annual domestic demand increase of 4 percent over the next decade.

ZINC

Zinc enters the problem only to the extent that it is used in the brass connector shells. This metal is experiencing the same type of problems as copper only to a greater degree. The environmental controls placed upon zinc smelting have caused several smelters to close, resulting in a 40-percent decrease in domestic production capacity between 1968 and 1973. Thus, today over 60 percent of our zinc is imported. The supply of domestic zinc is subject to possible reduction. However, this may be mollified by decreased demand resulting from substitution of plastics for many products now made from zinc. The projected price change to year 2000 is zero.

PLASTICS (PETROCHEMICAL)

The two plastics used in the coaxial cable (PTFE and FEP) contribute 8 percent of the total coaxial cost. Plastics, in general, can be expected to increase in cost and are likely to be in short supply throughout the next decade. The reason for this is the demand for petroleum products as energy supplies. Two of the major materials used in the above plastics are propylene and ethylene. Propylene has fuel value and has been in chronically short supply during the past several years. Ethylene is made from ethane and propane. Propane is an excellent substitute for natural gas and is one of the heating gases in critical supply. As the oil supply has tightened up, a large share of our most important plastics feedstocks, ethylene, propylene, and benzene have been diverted to use as fuels. The wholesale price index of plastics had a general downward trend from 1967 to 1972 and since has had an upward trend due to the demand for petroleum.

SILVER

Silver is used in both the coaxial inner and outer conductor as well as in the connector shells, and is the major material cost contributor for the coaxial cable.

The projected increase in the price of silver from 1968 through 2000 is from $2.14 to $2.50 per troy ounce or an average yearly increase of 0.53 percent. The United States currently depends on imports for 50 percent of its silver. An historical account of the price of silver from 1930 to 1975 is shown in figure B-5. The dashed line shows the price index change for mining from 1960 through 1974. It can be seen that the increase in silver price since 1965 has been significant.

The cost projections for the A-7 ALOFT Economic Analysis have been completed. The general trend for DOD procurement inflation for the period 1975 through 1980 is shown in figure B-6. The projected price increase for the materials used in the wire interface system is also shown. This line was developed by weighting the projected yearly average increase for each material according to its current contribution to system material cost. The weighted average of all contributors was calculated to determine the price increase above inflation.

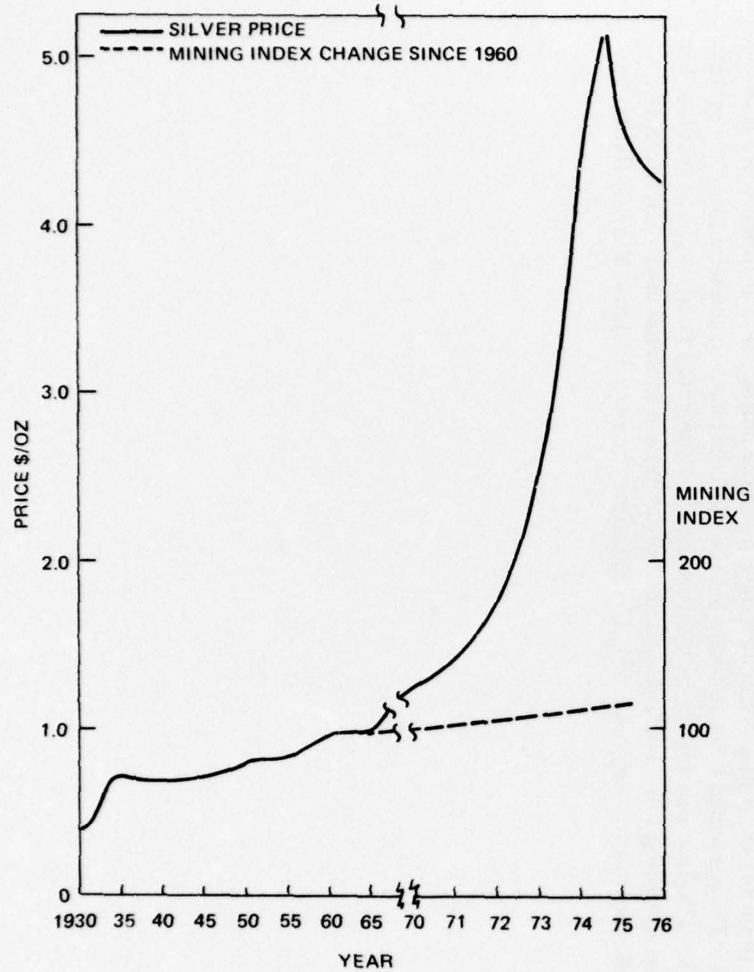

Figure B-5. Historical price of silver, 1930 to 1975.

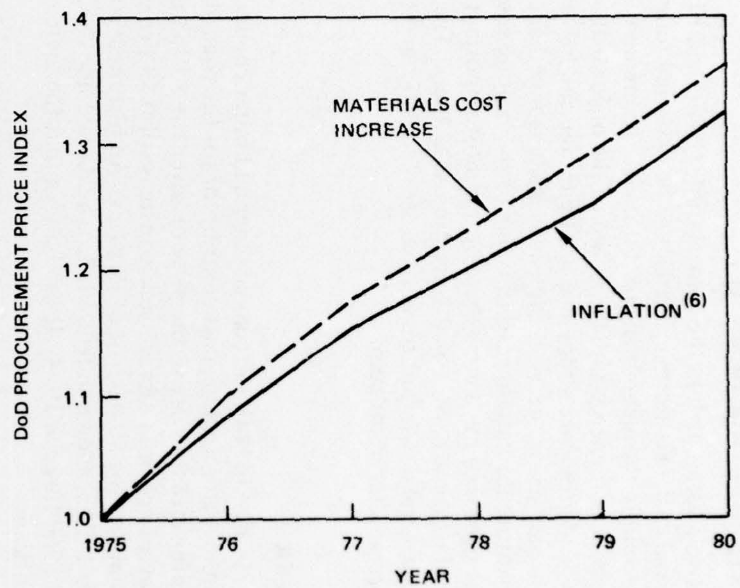

Figure B-6. DoD procurement inflation, 1975 to 1980.